The best choice of fertilizer for maize (*Zea mays*) and climbing beans (*Phaseolus vulgaris*) rotation for rich, mean and poor farmers in South Kivu, D.R. Congo

Accepted 20th February, 2015

ABSTRACT

Many studies on fertilization of both beans and maize have been done, but most of the farmers don’t implement the recommendations because they can not afford the fertilizers’ cost at the recommended rate. From February 2008 to June 2010, an experimental study was conducted to investigate the effect of NPK, manure and a mixture of NPK and manure, to the rates that rich, mean and poor farmers can afford. The rich farmers could afford the recommended rate, the mean farmers could afford the half and the poor ones could only afford the quarter. After the first season, the rate of fertilizer was updated according to the income gained from the previous season’s production by each farmer type. For the five seasons of the trial, NPK gave the best yield for both crops, followed by the mixture and then manure for rich and mean farmers, but for poor farmers all the fertilizers gave almost the same result. But in water excess condition manure gave more stability of the climbing beans production, while the NPK’s outcomes were very unstable and the mixture gave an intermediate result. Farmers who didn’t apply fertilizers had the lowest yield. The farmers’ income followed the same evolution as their yield but not their investment capacities. All the fertilizers increased the investment capacity so as after four seasons, even poor farmers could afford the recommended rate. The fastest increase was obtained by both the mixture and NPK, followed by the manure alone and the lowest increase was obtained by farmers who didn’t use any fertilizer. The results of this study recommend improving agricultural productivity by increasing the use of inorganic fertilizers.

Key words: Rotation, fertilizer, manure, NPK, investment capacity.

INTRODUCTION

The CAADP\(^1\) has set a goal of 6% annual growth rate in agricultural production to reach the UN’s Millennium Development Goal of halving poverty and hunger by 2015 (Sanginga, 2010). But the Democratic Republic of Congo’s growth rate is only 2% though the population growth rate is 3.1% (Hatungimana, 2001). That situation makes hunger and malnutrition to become the characteristics of sub-Saharan Africa (Conceicao et al., 2011). In South-Kivu, 42% of illness cases are due to malnutrition (Gaye, 2010). The low production is due to both the fact that farmers has a little space because of the high demographic pressure on South-Kivu lands (Gaye, 2010; DSRP, 2005), and to the little yield of most of the crops in D.R. Congo (FAO, 2010). The low yield is due mostly to the low fertility of the lands and fertilization is the best solution for that problem (Sebilotte, 1989; Debreczeni and Berecz, 2000; Marton, 2004). Unfortunately in South-Kivu, as in many tropical regions,
Table 1. Rate of fertilizer applied by different type of farmers according to choice of fertilizers for B 2008, A 2009, B 2009, A 2010 and B 2010 seasons.

<table>
<thead>
<tr>
<th>Type of farmer</th>
<th>Choice of fertilizer</th>
<th>B 2008</th>
<th>A 2009</th>
<th>B 2009</th>
<th>A 2010</th>
<th>B 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manure</td>
<td>5000</td>
<td>0</td>
<td>5000</td>
<td>0</td>
<td>5000</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>0</td>
<td>200</td>
<td>0</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mixture</td>
<td>2500</td>
<td>100</td>
<td>2500</td>
<td>100</td>
<td>2500</td>
</tr>
<tr>
<td>Rich</td>
<td>Manure</td>
<td>2500</td>
<td>0</td>
<td>2925</td>
<td>0</td>
<td>3024</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mixture</td>
<td>1250</td>
<td>50</td>
<td>2500</td>
<td>100</td>
<td>2500</td>
</tr>
<tr>
<td>Mean</td>
<td>Manure</td>
<td>1250</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5000</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mixture</td>
<td>625</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>2500</td>
</tr>
<tr>
<td>Poor</td>
<td>Manure</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mixture</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The cost and availability of fertilizers is a constrain for production (Sanchez, 1976; Hinsinger, 2001; Brathwaite, 2008).

Fertilizer should increase the yield and by the same way the income and the investment capacity. Inorganic fertilizers should give a highest yield than organic ones. Mixture of both should give an intermediate result. Inorganic fertilizers should also give the highest income. Mixture should give the highest investment capacity because of its production which is almost the same as the inorganic fertilizers one and because of its price which is intermediate between manure’s one and NPK's one.

The objectives of this work was to determine the best choice of fertilizer according to the farmer’s investment capacity, to know if a poor farmer who is not able to start with the recommended rate of fertilizers can increase his incomes until he is able to respect the recommendation.

MATERIALS AND METHODS

The trial

The trial was realized at INERA²/Mulungu which is the research station for the D.R. Congo highlands. Two crops (Maize and climbing bean) have been used according to their importance in the region. Maize was chosen because it’s among the most important food in D.R. Congo after cassava and plantain (FAO, 2010) and beans because it's the main source of protein in the African Great Lakes region (Baudouin et al., 2001) The climbing beans were cultivated from February to June 2008, 2009 and 2010 (B seasons) and maize from September 2008 and 2010 to January 2009 and 2010 (A seasons). The rate of fertilizer used in February 2008 was calculated according to the farmers' investment capacity. But after the June 2008's harvest, their investment capacity changed and they afforded a different rate of fertilizers (Table 1). The weather was not a source of variation but let mention that there was a rain excess in February 2009 (INERA, 2009).

The trial was realized in a completely randomized design, with four blocks and ten treatments during five seasons.

Farmers situation

The CIALCA investigation showed that rich, mean and poor farmers were characterized by the farm size (respectively 1.33, 0.72 and 0.35 hectares), income from family work (respectively US $42, 2 and 0), yearly expenses (US $739, 286 and 147), income from other activities (US $59, 12 and 0), numbers of goats (2, 1 and 0), maize yearly consumed (425, 273 and 228 kg) and beans yearly consumed (147, 95 and 78 kg). The average number of family members is 7 and the part of the farm reserved to maize and beans crops is 20%.

The farmers income was calculated by the following formula: R=([Y*S] – A)*P:

where: R: income, Y: yield, S: farm’s surface, A: auto consumed food, P: production price

The farmer’s investment capacity was calculated by: I=(R – E)/(C*S):

And it's according to these characteristics and to the yield that the rate of fertilizers was estimated for the next season.

**Rates and application of fertilizers**

Manure was manually mixed with the soil after sampling. That was done on the whole field’s surface. NPK was put in a furrow near the seeds’ row so that the roots could easily access it. For A seasons, urea was added when the maize plants was as high as human knees (50 cm) in the same way as NPK. For applying the mixture of manure and NPK, manure was applied first like described below and then NPK was added in the furrows and for A seasons urea was added a little time after.

**Data analyses**

R guiw was used for analysis of variance and comparison of mean, and Microsoft Excel was used for figures design.

**RESULTS**

**Yields**

For the farm management, the social position of the farmer is very crucial. The poor is likely less able to use the good rate of input for the yield improvement. The figures below (1-6) gave the yields for the maize and beans for the different category of farmers.

For rich farmers NPK and mixture fields had the highest beans yield an average of 1129.33 and 1082.33 kg/ha, followed by manure with 939.67 kg/ha and at least the fields without fertilizers was 745.67 kg/ha.

For rich farmers, the NPK fields had the highest maize yield with 6399.50 kg/ha of average, followed by mixture (5433.00 kg/ha), followed by manure (4237.50 kg/ha) and at least unfertilized fields (2679.50 kg/ha).

For poor farmers, NPK and mixture had the highest beans yield (1095.67 and 1084.00 kg/ha), followed by manure (980.33 kg/ha) and the unfertilized fields had least yield (745.67 kg/ha).

For poor farmers, NPK and manure had the highest maize yield (4250.50 and 4118.50 kg/ha), followed by mixture (3398.50 kg/ha) and the unfertilized fields had the least yield (2679.50 kg/ha).

**Income**

The income capacity for the different stakeholders involved in the study is given by the figures below (Figures 7-12).

For rich farmers, NPK fields gave the highest income from beans (US $167.57 of average), followed by mixture (US $153.75), followed by manure (US $116.71) and unfertilized fields gave the least income (US $71.72).

For rich farmers, NPK field gave the highest income (US $412.55), followed by mixture (US $330.98), followed by manure (US $138.79) and the unfertilized fields gave the least income (US $107.59).

For mean farmers, mixture and NPK fields gave the highest income from beans (US $56.56 and 49.09), followed by manure (US $31.58). Unfertilized fields gave the least income (US $13.09).

For mean farmers, NPK field gave the highest income (US $461.84), followed by mixture (US $375.27), followed by manure (US $334.38). Unfertilized field gave the least income (US $130.88).

For poor farmers, mixture and NPK gave the highest income from beans (US $18.61 and 18.38) followed by manure (US $7.87). Unfertilized field gave the least income (US $2.82).

For poor farmers, NPK and manure gave the highest income from beans (US $46.51 and 43.52) followed by mixture (US $29.84). Unfertilized field gave the least income (US $14.43).

**Investment capacity**

Each category of farmer it's capacity of investment according to the social position (Figures 13-18).

For rich farmers, mixture gave the highest investment capacity (189.33%) followed by both manure and NPK (175.67 and 175.00%). Unfertilized fields gave the lowest investment capacity (75.00%), though the initial rich investment capacity was 100%.

For rich farmers, mixture gave the highest investment capacity (315.00%), followed by NPK (287.50%) and manure (209.00%). Unfertilized field gave the lowest investment capacity (75.00%).

For mean farmers, mixture gave the highest investment capacity (128.67%) followed by NPK and manure (94.67 and 87.67%). Unfertilized fields gave the lowest investment
Figure 1. Beans yield (kg/ha) of rich farmers for B 2008, B 2009 and B 2010 season.

Figure 2. Maize yield (kg/ha) of rich farmers for A 2009 and A 2010 seasons.

Figure 3. Beans yield (kg/ha) of mean farmers for B 2008, B 2009 and B 2010 seasons.

Figure 4. Maize yield (kg/ha) of mean farmers for A 2009 and A 2010 seasons.

Figure 5. Beans yield (kg/ha) of poor farmers for B 2008, B 2009 and B 2010 seasons.

Figure 6. Maize yield (kg/ha) of poor farmers for A 2009 and A 2010 seasons.

Figure 7. Income from beans (US $) of rich farmers for A 2008, A 2009 and A 2010 seasons.

Figure 8. Income from maize (US $) of rich farmers for A 2009 and A 2010 seasons.
For mean farmers, manure gave the highest investment capacity (929.00%) followed by mixture (659.50%) and NPK (594.00%). Unfertilized fields gave the lowest investment capacity (168.50%).

For poor farmers, mixture gave the highest investment capacity (87.33%) followed by NPK (73.00%) and manure (45.00%). Unfertilized fields gave the lowest investment capacity (12.00%). Fertilized fields increased the farmers' investment capacity upper than 100%.

For poor farmers, manure gave the highest investment capacity (248.50%) followed by NPK (123.00%) and mixture (107.50%). Unfertilized fields gave the lowest investment capacity (38.00%). Fertilizers increased the farmer's investment capacity higher than 100%.

**DISCUSSION**

**Yield**

Fertilizers increased the beans yield of 41% (Figure 1), at the recommended rate (for rich farmers) because N, P and K are constrains in most of the weathered tropical soils (Sanchez and Logan, 1992; Lynch et al., 2003).

Fertilizers increased the maize yield of 86% (Figure 2). The superiority of fertilizers' effect on maize is due to the fact that maize used N which was left by beans (Bagayoko et al., 1996) and because of the changes of microbiological activities after legumes (Shipton, 1977; Turco et al., 1990) and VAM (vesicular and arbuscular micorrhizae) which allow the maize plant to absorb more P (Johnson et al., 1992; Bainville et al., 2005).

On the mean farmers rate fertilizers increased the beans yield of 54% (Figure 3), more than the increase of fertilizers to the rich farmers' rate. Pypers et al. (2010) found the same result on cassava and legume intercrop system in a similar soil in Kabamba.

But for maize the yield was increased by 94% (Figure 4) due to the fact that poor farmers' rate of fertilizers application increased the beans yield by 41% (Figure 5), less than the increase shown on mean farmers' rate. The fertilizer's effect was so low that the increase seen is mostly due to the farm size that allowed the application of fertilizers very well (Anson et al., 2009).

For maize the yield was increased by 46% (Figure 6), less than the increased shown for farmers because of the very little rate of fertilizers application.

Among the fertilizers, NPK gave the highest yield for rich and mean farmers mostly because it contains more nutrient than manure and mixture which is intermediate to the two fertilizers. And also manure must go through a long mineralization process so that its contents, especially P, can be available for the crop (Nachimuthu et al., 2009; Berger, 1996).

For poor farmers all the fertilizers gave almost the same
result because the rate wasn’t enough to show the differences among fertilizers’ effect.

When there was the problem of excess rain in February 2009 (INERA, 2009), manure showed more stability to the yield. This was due to the effect of manure on soil’s structure (Cambardella and Elliott, 1992; Six et al., 2002). Manure allows a better water circulation in the soil. Also inorganic fertilizers’ content easily runoff with the soil water movement (Chien et al., 2009). Mixture showed an intermediate stability because it gives an intermediate level of stability because it contains half the quantity of manure.

**Income**

Fertilizers increased the income of the rich farmers by 104% (Figure 7) from beans production and 170% (Figure 8) from maize production, though the yield was increased respectively by 41 and 86% (Figures 1 and 2). That was due to the fact that the rich farmers consume 425 kg of maize and 147 kg of beans per year (CIALCA, 2010) and it’s the produce left that they sell, which will vary more than the yield variation.

For mean farmers, the fertilizers increased the income by 250 and 198% (Figures 9 and 10) respectively from beans and maize production, though the corresponding increase yield due to fertilizers was 54 and 94% (Figures 3 and 4).

For poor farmers, the fertilizers increased the income by 430 and 177% respectively (Figures 11 and 12) from beans and maize. This increase is due to the fact that poor farmers who do not use fertilizers can hardly produce enough to feed their family, especially for beans. So the fertilizers, by allowing them to produce enough to have something left for sell highly increase their income, compared to the corresponding increase in yield which was 41 and 46% respectively.

The highest income was obtained by farmers who used NPK, followed by those who used mixture and then those who used manure. That was due to the difference in yield and also due to the application of fertilizers.

**Investment capacity**

Fertilizers increased the rich farmers’ average investment capacity of 140% applied to beans and 261% for the maize (Figures 13 and 14), because by increasing the farmers production he could have enough money for his expenses (CIALCA, 2010) and still have enough to invest in fertilizers.

For mean farmers, fertilizers increased the average investment capacity respectively by 304 and 332% (Figures 15 and 16) when applied to beans and maize. That was due to the following reasons: For poor farmers, fertilizers increased the average investment capacity respectively by 470 and 320% (Figures 17 and 18) when applied to beans and maize. That was due to the fact that mixture gave the
highest investment capacity for the five seasons because it costs less than the NPK (CIALCA, 2010) and gives a yield which is almost the same as NPK, because manure improves the efficiency of the NPK it was mixed with (Vanlauwe et al., 2001). It was followed by NPK because of its high yield. Then finally manure gave the least investment capacity among the three types of fertilizer.

For poor and mean farmers all the fertilizers allowed them to get to the recommended rate after a maximum of four seasons. That was due to the fact that all the money left after the family expenses were invest in fertilizers in order to get recommended rate according to the initial hypotheses.

Conclusion

Our results show that using fertilizers can increase the yield at any rate. They also show that NPK when used alone is the best fertilizer for increasing the yield and the farmer’s income. But the mixture of both NPK and manure was the best way of increasing the investment capacity and so allow them to apply the recommended rate of fertilizers.

ACKNOWLEDGEMENT

The authors thank CIALCA for funding this study and all technicians who have been involved in data collection.

REFERENCES


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