Agronomic and financial analysis of maize-legumes production in western Kenya

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Abstract

Maize (Zea mays L.) and grain legumes are the dominating crop enterprises in western Kenya. Whilst maize provides the backbone to food security, grain legumes are multi-functional sources of household protein, fix atmospheric nitrogen to the soil and provide livestock feed. maize yield is typically less than 1.0 tons per hectare (t ha⁻¹) against the potential of 5.0 t ha⁻¹ whilst legume yields are less 0.2 t ha⁻¹ relative to potential 2.5 t ha⁻¹ obtainable under research, mainly due to low soil fertility. Against this backdrop, during long rain seasons in the years 2010 and 2011, 24 on-farm demonstrations were set up to disseminate Integrated Soil Fertility Management (ISFM) technologies in four sub-Counties in western Kenya. The demonstrations were designed in a Randomised Complete Block Design involving four treatments: 1. Maize-bean; 2. Maize-soybean, 3. Sole maize (control) and 4. Maize-groundnut intercrops. The objectives of this study were to evaluate effect of different maize-legume intercrops on maize and legume grain yields; and to analyse costs and benefits of the maize-legume intercrops. Data were collected on maize and legume yields, quantities of inputs applied and prices of both inputs and outputs. Results showed that the highest maize grain yields (4.8 t ha⁻¹) were obtained from maize-bean, followed by maize-groundnut (4.7 t ha⁻¹) intercrops. Amongst the legumes, soybean gave the highest grain yield (0.5 t ha⁻¹). The highest benefit-cost ratio of 2.5 was obtained from maize-bean intercrop and the lowest (1.9) was from sole maize (without fertilizer) mainly because beans had the highest demand and market price per unit. As such, there is need to develop policies that promote smallholder farmers’ access to efficient input and output markets.

Keywords: Benefits, costs, demonstrations, intercropping, soil fertility.

Introduction

The need for sustainable intensification of agriculture in sub-Saharan Africa (SSA) has gained support, in part because of the growing recognition that farm productivity is a major entry point to break the vicious circle underlying rural poverty. Landmark events to promote agriculture in Africa include the African Heads of State Fertilizer Summit held in Abuja, Nigeria in 2006 (IFDC, 2006) and the launching of the Alliance for a Green Revolution in Africa (AGRA). Kofi Annan, former the Chairman of the Board of AGRA, has repeatedly stressed that the African green revolution should be made uniquely African by recognizing the continent’s great diversity of landscapes, soils, climates, cultures and economic status, while also learning lessons from earlier green revolutions in Latin America and Asia (United Nations, 2004)

Maize (Zea mays L.) and grain legumes are the dominating crop enterprises in western Kenya. Whilst maize provides the backbone to food security, grain legumes are multi-functional sources of household protein, fix atmospheric nitrogen to the soil and provide livestock feed. The yield of maize -the staple food crop- in the densely populated Western Kenya is, however, typically less than 1.0 tons per hectare (t ha⁻¹) against the potential of 5.0 t ha⁻¹. Legume yields are equally low, at less than 0.5 t ha⁻¹ relative to potential of 2.5 t ha⁻¹ (KARI, 2013). Maize production has, therefore, not kept up with the population growth leading to serious food insecurity and poverty (Odendo et al. 2009). The low yields in western Kenya have been blamed on soil degradation and Striga weed menace on maize (KARI, 2013).

Reversing the low and declining crop yields in western Kenya requires increasing investments in technologies that improve soil fertility and control of the Striga weed, whilst improving farmers’ access to improved seeds and output markets. Several proven integrated soil fertility management (ISFM)
technologies that could improve crop yields have been developed and disseminated in western Kenya. These include inorganic fertilizers and organic inputs such as farm yard manure and grain legumes. The most promising grain legumes in Western Kenya are soybeans (Glycine max), groundnuts (Arachis hypogaea), common beans (Phaseolus vulgaris) and climbing beans (Vigna umbellata). These grain legumes can be taken to scale in Western Kenya either in rotation or as intercrops with cereals, especially maize.

Improved maize-legume intercropping systems are part of ISFM technologies (Mucheru-Muna et al., 2010; Shyamal and Patra, 2013) that are currently receiving global attention because of their prime importance in World Agriculture, though intercropping in itself is an age-old practice. According to Bationo et al. (2011), intercropping maize with legumes is one of the most common cropping systems in Africa. However, in Western Kenya there is dearth of knowledge on agronomic performance, costs and benefits of intercropping. Against this backdrop, on farm demonstrations involving intercropping of maize with different legumes were conducted in four sub-Counties in Western Kenya to create awareness on maize-legume intercrops and disseminate ISFM options. As part of the on farm demonstrations, the objectives of this study were to: evaluate effect of different maize-legume intercrops on maize and legume grain yields; and analyse costs and benefits of the maize-legume intercrops. The findings of this study assist farmers, researchers and development agencies in making informed decisions on maize legume intercrops for improved productivity.

Materials and methods

The study area

The study was conducted in Emuhaya, Kakamega South, Mumias and Gem sub-Counties of western Kenya (Figure 1). These sub-Counties were purposively chosen to represent varying farming circumstances. Emuhaya, Mumias and Gem fall in the Lower Midland (LM) Agro ecological zone, whilst Kakamega South is predominantly in the Upper Midland zone with higher agricultural potential compared to LM (Jaetzold et al., 2006).

![Figure 1: Geographical location of the study sites in Western Kenya](image)

Experimental design

During the long rain cropping seasons of 2010 and 2011, on-farm demonstrations were set up in - Kakamega South, Mumias, Emuhaya and Siayasub-Counties. The demonstrations consisted of four treatments: 1. maize-bean; 2. maize-soyabean, 3. maize monocrop, and 4. maize-groundnut. The treatments were selected by researchers and extension agents in consultation with farmers. The demonstrations were laid out in randomized complete block design (RCBD), each treatment occupying 10 x 10 m plot and replicated on 12 farms per season for two seasons. Recommended fertilizer rate of 60
kg N ha\(^{-1}\) and 26 kg P ha\(^{-1}\) was applied. Maize was planted at 75×30 cm and legumes were inter-cropped following recommended spacing of 10 cm intra-row spacing.

**Data collection and analysis**

Agronomic data that was collected included maize and legume yields, whilst economic data entailed production costs and benefits of each treatment. In estimating the cost of production, only the variable cost items were considered. The variable costs were the expenditure on legume seed and labor. Other costs such as those of fertilizers, maize seed, and weeding were constant across the treatments and not applied in this analysis. The agronomic data were evaluated by Analysis of Variance (ANOVA) and Benefit cost ratios (BCR) were applied in financial analysis.

Benefit-cost analysis provides a framework for predicting the likelihood of adoption of ISFM options using the principles of (1) economic threshold: act only if the benefits of acting outweigh the costs, and (2) input/output optimization: when choosing among multiple options such as ISFM, choose the one that maximizes net benefits (Walker, 2012). Under this general framework, a farmer is expected not to choose a given ISFM strategy unless the net benefit of doing so is positive. Following Dixon and Hufschmidt (1986) benefit - cost ratio was calculated as: Total Revenue (TR)/Total Variable Costs (TVC). The TR was obtained by adding income from maize and legume grains, while total cost was obtained by adding all the expenditures that varied across treatments in the production process. An option with higher ratio is more profitable. A benefit-cost ratio lower than one means the option is not profitable.

**Results and discussion**

**Maize yields**

The highest mean grain maize yields were obtained from maize-bean, followed by maize-groundnut treatments. Analysis by sub-Counties shows that the highest grain maize yield (6.8 t ha\(^{-1}\)) was from maize - groundnut intercrop in Mumias sub-County (Table 1). The lowest yield was from sole maize, planted without fertilizer as a control. There were significant differences between the control and the other treatments in all study sub-Counties except in Emuhaya sub-County. A similar study by Nzabi et al. (2000) in Kisii Kenya showed that maize intercropped with soybeans gave yield of 3.2 t ha\(^{-1}\) whilst sole stand of maize with no crop residue incorporation, as was in this study, had the lowest mean grain yield of 2.9 t ha\(^{-1}\).

**Table 1: Maize grain yields (t ha\(^{-1}\)) in maize-legume intercrops in Western Kenya (Long rains 2010 and 2011)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Emuhaya</th>
<th>Gem</th>
<th>Kakamega South</th>
<th>Mumias</th>
<th>Pooled mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize-bean</td>
<td>4.08</td>
<td>4.89</td>
<td>3.76</td>
<td>6.12</td>
<td>4.77</td>
</tr>
<tr>
<td>Sole maize</td>
<td>1.16</td>
<td>2.88</td>
<td>0.9</td>
<td>0.31</td>
<td>1.02</td>
</tr>
<tr>
<td>Maize-groundnut</td>
<td>1.69</td>
<td>4.13</td>
<td>4.64</td>
<td>6.82</td>
<td>4.72</td>
</tr>
<tr>
<td>Maize soyabean</td>
<td>2.77</td>
<td>3.7</td>
<td>3.83</td>
<td>5.94</td>
<td>4.41</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>2.68</strong></td>
<td><strong>3.9</strong></td>
<td><strong>4.14</strong></td>
<td><strong>6.32</strong></td>
<td><strong>4.6</strong></td>
</tr>
<tr>
<td>LSD (P&lt;0.05)</td>
<td>3.46</td>
<td>1.69</td>
<td>1.37</td>
<td>1.54</td>
<td>1.36</td>
</tr>
<tr>
<td>CV (%)</td>
<td>36.68</td>
<td>21.74</td>
<td>34.16</td>
<td>21.9</td>
<td>35.11</td>
</tr>
</tbody>
</table>

Means with the same letter in the same column are not significantly different at (P<0.05)

Source: Authors’ analysis of on-farm demonstrations (2010 and 2011)
With regard to legume yields, again there were no significant yield differences across sites (Table 2). However, the highest yield was obtained from maize-bean intercrop in Emuhaya sub-County. This could be attributed to the growth habit of the beans which enables it to be more compatible with maize. The general low yields of legumes could be attributed to the high incidences of legume diseases (e.g., bean root rot, anthracnose) and pests (e.g., aphids) during the long rains, when moisture and temperatures are conducive for prevalence of diseases and pests.

Table 2: Legume yields (t ha⁻¹) in maize-legume intercrops in Western Kenya (Long rains 2010 and 2011)

<table>
<thead>
<tr>
<th>Sub-County</th>
<th>Beans</th>
<th>Groundnut</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emuhaya</td>
<td>0.72a</td>
<td>-</td>
<td>0.25a</td>
</tr>
<tr>
<td>Gem</td>
<td>0.61a</td>
<td>0.61a</td>
<td>0.26a</td>
</tr>
<tr>
<td>Kakamega South</td>
<td>0.54a</td>
<td>0.22a</td>
<td>0.46a</td>
</tr>
<tr>
<td>Mumias</td>
<td>0.30a</td>
<td>0.21a</td>
<td>0.32a</td>
</tr>
<tr>
<td>LSD (P&lt;0.05)</td>
<td>0.62</td>
<td>0.41</td>
<td>0.34</td>
</tr>
<tr>
<td>CV (%)</td>
<td>31.23</td>
<td>18.62</td>
<td>27.81</td>
</tr>
</tbody>
</table>

Benefit-cost analysis of maize-legume intercrops in Western Kenya

Benefit-cost analysis (BCA) of the 2010 and 2011 long rains seasons maize and legume crop yields indicate that the maize-bean intercrop yielded both the highest net benefits of KSh. 57,216 and benefit-cost ratio (BCR) of 2.5 followed by maize-groundnut (2.1). Sole maize crop gave the lowest BCR (Table 3).

Table 3: Benefits and costs of maize-legume intercrops in Western Kenya (Long rains 2010 and 2011)

<table>
<thead>
<tr>
<th>Cost/Revenue Item</th>
<th>Maize-bean</th>
<th>Maize-groundnut</th>
<th>Maize soyabean</th>
<th>Sole maize (no fertilizer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize revenue</td>
<td>85860</td>
<td>84960</td>
<td>79380</td>
<td>16524</td>
</tr>
<tr>
<td>Legumes revenue</td>
<td>10800</td>
<td>5670</td>
<td>2880</td>
<td>0</td>
</tr>
<tr>
<td>Total Revenue</td>
<td>96660</td>
<td>90630</td>
<td>82260</td>
<td>16524</td>
</tr>
<tr>
<td>Total Variable costs</td>
<td>39444</td>
<td>43179</td>
<td>39754.5</td>
<td>9088.2</td>
</tr>
<tr>
<td>Net Benefit</td>
<td>57216</td>
<td>47451</td>
<td>42505.5</td>
<td>7435.8</td>
</tr>
<tr>
<td>Benefit /cost ratio (BCR)</td>
<td>2.45</td>
<td>2.10</td>
<td>2.07</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Treatments that had higher net benefits also had a higher benefit-cost ratio (BCR) as exemplified by results in Table 3. It is, however, noteworthy that net benefit alone could be misleading as far as cost effectiveness of the different soil fertility amendment inputs is concerned. Therefore, BCR seems to be the most appropriate and convenient economic tool for determining the most economical soil fertility amendment technologies because it is a comparison between net benefits and costs thus showing the return per shilling invested. The factors associated with differential BCR amongst the treatments include field cost of legume seed, grain legume prices and cost of labour.

The findings support an earlier study conducted in Western Kenya by Odendo and Kalybara (2004) that found that changing from sole maize cropping to maize-bean intercropping resulted in a Marginal
rate of return (MRR) of 370%, in which they concluded that growing maize in association with beans was overwhelmingly advantageous compared with planting maize as a sole crop. Similarly, Mucheru-Muna et al. (2010) found out that legume intercrop increased crop yields and economic benefits in the highlands of Central Kenya. Moreover, Yilmaz et al. (2008) reported 65-34% increase in monetary profit per unit area in intercropping legumes with maize compared to sole legume or sole maize planting.

Overall, this study confirms that maize-legume intercropping systems are a sound means of yield improvement for the fact that it involves integrating crops through efficient use of resources, reductions in costly inputs (Morris and Garrity, 1993) and increase in productivity per unit of land per unit time (Sullivan, 2003). One of the main reasons for higher yield in intercropping is that the component crops are able to use growth resources differently, so that when grown together, they complement each other and make better overall use of growth resources than when grown separately (Willey, 1979; Shyamal and Patra, 2013). Besides, intercropping leads to equitable and judicious utilization of land resource and inputs including labour, whilst providing insurance against crop failure (Singh and Bajpai, 1991).

Conclusions and recommendations

There were significant differences in maize grain yields, except in Emuhaya sub-County. The highest maize grain yields (4.8 t ha⁻¹) were obtained from maize-bean, followed by the maize-groundnut (4.7 t ha⁻¹) intercrops. Similarly, there were no significant differences in legumes grain yields across the study counties. Amongst the legumes, soybean gave the highest grain yield (0.5 t ha⁻¹). The highest benefit-cost ratio of 2.5 was obtained from maize-bean intercrop and the lowest (1.9) was from sole-maize crop.

From the findings of this study, research should explore more innovative maize-legume intercropping and rotational systems that optimize the yields of both legumes and maize. This should involve intercrop patterns and development of an improved strategies for controlling legume diseases and pests. The findings of this study also point to the need to develop policies that promote smallholder farmers’ access to efficient input and output markets.

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References


