Yield and yield components of local cowpea (Vigna unguiculata L.) landraces grown in mixed culture with maize (Zea mays L.) in vertic cambisols in the Northern part of Tanzania

Abstract

Smallholder farmers in the North eastern Tanzania practice cereal-legume mixed culture to manage risks of crop failure in sole crops. The production and productivity of cereal-legume intercrops may be influenced by the practice of cultivating two or more crops in the same space and time and the status of land races/cultivars involved as intercrops. Data on the effect of intercropping system on cowpea landraces with maize grown on Vertic Cambisols on yield and yield components are inadequate in the North eastern Tanzania although considerable knowledge has been accumulated on mixed culture system. A field experiment involving two cropping systems (sole crop and intercropping) was therefore conducted for two years (2017 and 2018) at Shirimutanda village, Kilimanjaro Region, North East Tanzania, to evaluate three local cowpea (Vigna unguiculata L.) landraces (i.e. landrace 1 (L1), landrace 2 (L2) and landrace 3 (L3)) grown in association with maize (Zea mays L). Intercropping significantly (P≤.05) decreased cowpea and maize yields. Performance of local cowpea landraces, however, did not show (P≤.05) any variation except for 100–seed weight where cowpea landrace 2 (L2) showed superiority compared with the other cowpea landraces. Although there was no significant variation in maize yield when intercropped with cowpea landraces, maize intercropped with cowpea landrace 1 gave numerically the highest grain yield. Regardless of cropping system and cowpea landraces, combined productivity of cowpea and maize increased in the intercropped plots as indicated by higher total land equivalent ratios (1.64 to 1.94). Highest LER, value was observed in the ‘Cowpea landrace 1’+Maize mixed culture. The observed total land equivalent ratio (LER) values correspond to 48.25, 38.54 and 43.66 % of lands saved which could be used for other agricultural purposes. In these cropping systems, both cowpea landrace 1 & 3 and maize crop components were significantly complementary and most suitable in mixed culture as shown by competitive ratio (CR) values of 1.85 and 1.45 respectively.

Keywords: mixed culture, Shirimutanda, landrace, cowpea, genotype, yield components

Introduction

Intercropping, one of the cropping systems in developing countries, is a practice by smallholder farmers of cultivating two or more crops in the same space and time, with a view to minimize risks of crop failure due to weather variability. With this type of cropping system all the environmental resources are utilized for the maximization of crop production and productivity. In Tanzania and elsewhere in the tropics, intercropping is mostly practiced by small scale farmers characterized by subsistence agriculture, low agricultural mechanization, high labour and low - yield farming on small parcels of land. Since intercropping has been reported to increase both the amount of biomass, crop yield per unit area of land harvested and crop failure mitigation, farmers in the area practices mixed culture systems with a view that if one crop fails during the cropping season due to unequal distribution of rainfall and variability the other intercrop will be available for the household. According to Rusinamhodzi et al. intercropping can support increased aggregate yields per unit input, and thus ensure improved soil quality, food security and poverty alleviation through increased income. Several other benefits with regards to intercropping has been highlighted as increased land use efficiency; light capture and its use, soil moisture and nutrients; controlling weeds, insects, and diseases, increase in the length of production cycles; improved seed quality and better control of water quality through minimizing the use of inorganic N fertilizers, replacing them by the use of legumes. Typically this cropping system include maize (Zea mays L), millet (Pennisetum glaucum L) and sorghum (Sorghum bicolor L) as cereal crops components and beans (Phaseolus vulgaris), cowpea (Vigna unguiculata L), groundnut (Arachis hypogaea), pigeonpea (Cajanus cajan) and soybean (Glycine max) as legume crops components. However, in this study maize was intercropped with different types of cowpea local variety as used by local farmers. It has been shown that leguminous plants can benefit the intercrop cereals during the same season through N excretion and nodule decomposition, although according to Senaratne et al. each legume specie has different ability to supply N to its corresponding associated cereal neighbor. It is similarly assumed that intercropping cereals with legume crops, is that the legume, when associated with
Yield and yield components of local cowpea (Vigna unguiculata L.) landraces grown in mixed culture with maize (Zea mays L.) in vertic cambisols in the Northern part of Tanzania

Materials and methods

The study was conducted at the backyard garden in Osterbay Shirimatunda in the Northern Tanzania (3°22’S, 37°19E, and altitude 853.7 m a.m.s.l.) during the Masika rains growing seasons of 2017 and 2018. The study area receives mean annual rainfall of about 946 mm (Table 1). The average mean annual low temperature is 15.5°C and maximum annual high temperature is about 33.3°C with possibility of rising to 40°C during the dry season. The mean annual potential evapotranspiration (ETo) as measured by Penman Monteith (Monteith, 1965) was 1.390 mm (Table 1). The soil is clay classified as Vertic Cambisol in the FAO soil classification system. Prior to planting each year, soil samples (0 to 20 cm soil depth) were collected from the experimental plots, pooled, and sub-samples taken for chemical analysis. The soil physico-chemical properties are shown in (Table 2).

The experimental variables included three local cowpea landraces (‘mixed colour’; ‘black’; and ‘light brown colour, Figure 1), and two cropping systems (sole cowpea/maize and cowpea+maize intercropping). A two factor completely randomized block design was used with three replicates. Plot size of 3mx2.6m (7.8m²) was used for maize and cowpea. Cowpea was sourced from Kibo Seed Company and was grown at a spacing of 75x60cm to maintain a uniform density of 22.222 plants•ha⁻¹. Cowpea seeds were obtained from Moshi Municipality local markets, and were grown at a spacing of 20 x 40cm with a population of 125,000 plants ha⁻¹. All seedlings were later thinned to two per hole. Weeding was done manually to all crops with a hoe four times until harvesting. Fertilizer was applied for both sole and intercropped maize using the recommended rate. DAP was applied at the rate of 100kg ha⁻¹ at planting. Urea at the rate of 100kg ha⁻¹ was applied as top dressing in two splits one - third at 20 days after emergence (DAE), and two third at 40 DAE. The benefit of intercropping was quantified by LER which is defined as the relative land area in pure stands that is required under monoculture to produce the yields of all products from the mixture.

Table 1 Climate data representative of the study area (Moshi Airport, Lat. -3.35, Long. 37.35, Alt. 831 mamsl)

<table>
<thead>
<tr>
<th>Climate variable</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>D</th>
<th>Mean annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max (°C)</td>
<td>33.0</td>
<td>33.3</td>
<td>32.3</td>
<td>29.6</td>
<td>26.8</td>
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<td>25.6</td>
<td>26.6</td>
<td>28.7</td>
<td>30.8</td>
<td>31.9</td>
</tr>
<tr>
<td>Min (°C)</td>
<td>17.6</td>
<td>17.8</td>
<td>18.6</td>
<td>19.1</td>
<td>18.4</td>
<td>16.7</td>
<td>15.7</td>
<td>15.5</td>
<td>15.7</td>
<td>16.8</td>
<td>17.6</td>
</tr>
<tr>
<td>Mean (°C)</td>
<td>25.3</td>
<td>25.6</td>
<td>25.5</td>
<td>24.4</td>
<td>22.6</td>
<td>21.4</td>
<td>20.7</td>
<td>21.1</td>
<td>22.2</td>
<td>23.8</td>
<td>24.8</td>
</tr>
<tr>
<td>RH (%)</td>
<td>68.4</td>
<td>64.5</td>
<td>51.6</td>
<td>81.2</td>
<td>85.5</td>
<td>81.6</td>
<td>75.2</td>
<td>71.4</td>
<td>65.6</td>
<td>61.1</td>
<td>61.7</td>
</tr>
<tr>
<td>WS (km.d⁻¹)</td>
<td>198.7</td>
<td>198.7</td>
<td>178</td>
<td>156.5</td>
<td>110.6</td>
<td>110.6</td>
<td>133.1</td>
<td>155.5</td>
<td>199.6</td>
<td>244.5</td>
<td>288.6</td>
</tr>
<tr>
<td>WS (m.s⁻¹)</td>
<td>2.3</td>
<td>2.3</td>
<td>2.1</td>
<td>1.8</td>
<td>1.3</td>
<td>1.3</td>
<td>1.5</td>
<td>1.8</td>
<td>2.3</td>
<td>2.8</td>
<td>3.3</td>
</tr>
<tr>
<td>SH (hrs.d⁻¹)</td>
<td>5.3</td>
<td>6.0</td>
<td>5.0</td>
<td>4.8</td>
<td>3.6</td>
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<td>3.8</td>
<td>4.7</td>
<td>5.2</td>
<td>5.8</td>
<td>5.1</td>
</tr>
<tr>
<td>SR (M•m⁻²)</td>
<td>17.5</td>
<td>19.0</td>
<td>17.4</td>
<td>16.3</td>
<td>13.5</td>
<td>13.9</td>
<td>13.4</td>
<td>15.6</td>
<td>17.2</td>
<td>18.5</td>
<td>17.2</td>
</tr>
<tr>
<td>ET₀ (mm.d⁻¹)</td>
<td>4.3</td>
<td>4.7</td>
<td>4.8</td>
<td>3.5</td>
<td>2.7</td>
<td>2.7</td>
<td>2.8</td>
<td>3.3</td>
<td>4.0</td>
<td>4.7</td>
<td>4.8</td>
</tr>
<tr>
<td>ET₀ (mm.m⁻¹)</td>
<td>128.1</td>
<td>140.1</td>
<td>144.6</td>
<td>104.4</td>
<td>81.9</td>
<td>81.3</td>
<td>83.7</td>
<td>98.4</td>
<td>118.8</td>
<td>141.0</td>
<td>145.2</td>
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<tr>
<td>Rainfall (mm.m⁻¹)</td>
<td>42.6</td>
<td>46</td>
<td>113</td>
<td>318</td>
<td>141</td>
<td>29</td>
<td>22</td>
<td>14</td>
<td>15</td>
<td>37</td>
<td>81</td>
</tr>
</tbody>
</table>

Citation: Makoi J. Yield and yield components of local cowpea (Vigna unguiculata L.) landraces grown in mixed culture with maize (Zea mays L.) in vertic cambisols in the Northern part of Tanzania. Forest Res Eng Int J. 2019;3(3):88-94. DOI: 10.15406/frei.2019.03.00083
Yield and yield components of local cowpea (Vigna unguiculata L.) landraces grown in mixed culture with maize (Zea mays L.) in vertic cambisols in the Northern part of Tanzania

Table 2 Soil physical chemical properties of the study area

<table>
<thead>
<tr>
<th>BD</th>
<th>Texture (%)</th>
<th>pH 1:2.5 (H₂O)</th>
<th>Ca cmol (+) kg⁻¹</th>
<th>Mg g kg⁻¹</th>
<th>K mg kg⁻¹</th>
<th>Na</th>
<th>C</th>
<th>Av P cmol (+) kg⁻¹</th>
<th>CEC cmol (+) kg⁻¹</th>
<th>BS</th>
<th>ESP</th>
<th>C/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>SCL</td>
<td>7.0</td>
<td>16.6</td>
<td>0.2</td>
<td>85.0</td>
<td>0.6</td>
<td>21.0</td>
<td>1.0</td>
<td>85.0</td>
<td>12.0</td>
<td>149</td>
<td>5.0</td>
</tr>
</tbody>
</table>

BD, bulk density; pH, soil reaction; Ca, Calcium; Mg, magnesium; K, potassium; Na, sodium; C, carbon; N, nitrogen; P, phosphorus; CEC, cation exchange capacity; BS, base saturation; ESP, exchangeable sodium percentage; C/N, carbon nitrogen Ratio

Intercropping efficiency

Intercropping efficiency was evaluated by using land equivalent ratio, as given below:

\[ LER_c = \frac{YIC_c}{YM_{C}}; \quad LER_M = \frac{YIC_m}{YM_{M}} \]

Where LERc and LERm=Partial land equivalent ratio for cowpea and maize respectively; YICc and YICm=Mass yields per unit area of cowpea and maize in mixed culture respectively; YMc and YMm=Mass yields per unit area of cowpea and maize in monoculture respectively; LER=Total Land Equivalent Ratio. If LER is greater than one (LER>1), intercropping has a yield advantage while there is a yield disadvantage from intercropping if LER is less than one (LER<1).

Competition ratio and percentage land saved

Percentage (%) land saved was calculated as described in Ijoyah et al. and competitive ratio was calculated as described in Willey and Rao, as:

\[ CR = \frac{LER_m}{LER_c} \times 100 \]

Where: CR = Competitive ratio, LERm: Partial LER for maize; LERc: Partial LER for cowpea, and

\[ LS(\%) = 100 - \left( \frac{1}{LER_T} \times 100 \right) \]

Where: LS=Percentage land saved, LER=Total Land Equivalent ratio

At physiological maturity, the plants were counted and harvested. Yield assessment was carried from the middle rows of each plot excluding the border rows. Sixteen (16) plants of cowpea were sampled from each plot to determine the numbers of pods plant⁻¹ and seeds pod⁻¹. From the maize plots, eight plants were sampled for determination of the weights of head plant⁻¹ and seed plant⁻¹. Both cowpea pods and maize heads were manually threshed and allowed to air dry (~ 13 % moisture content). Grain yields of cowpea and maize were determined from each plot and 100 - seed weight and shelling percentage recorded. Mean values of yield components were analyzed statistically using a factorial analysis of variance (ANOVA) using the software, STATISTICA 2007 (StatSoft Inc., Tulsa, OK, USA). Fisher’s least significant difference was used to compare treatment means at P<.05.

Results and discussion

Intercropping cowpea (Vigna unguiculata L) with maize (Zea mays L) decreased (P≤.05) the weight of seeds plus pods plot⁻¹, weight of seeds plot⁻¹, weight of 100–seeds, grain yield and shelling per cent (Table 3). The decreased attributes as a result of mixed culture system is ascribed to the inter- and intra - specific competition for site resources typical of intercropping system treatments. The observed cowpea seed yield was on the average of 2.7 t ha⁻¹ in the monoculture and 1.9 t ha⁻¹ in the mixed culture plots (Table 3). Previous studies by Alom et al. showed that cowpea grain yield was (P≤.05) minimum when grown in mixed culture with maize compared with other treatment combinations. Intercropping cowpea with maize is characterized by a very low cowpea grain yields. Studies have also indicated that intercropping cowpea with maize (P≤.05) reduced cowpea yield by 43 %, the low productivity of cowpea in intercropping systems is due to among other reasons, to shading by cereals. Other studies by Nambiar et al. also reported similar negative effects for cowpea when intercropped with sorghum (Sorghum bicolor L).

Grain weight ear⁻¹, number of grains•row⁻¹ and 100-seed weight
of maize were significantly (P≤.05) lower at intercropping compared with monocropping (Table 4). Likewise, intercropping maize with cowpea landraces reduced (P≤.05) the ear length, grains row-1, ear diameter, total ear weight and shelling per cent of maize similar to results observed in Egbe et al. Maize seed yield was on the average of 3.5±0.2 t ha-1 in the sole crop and 3.1±0.1 t ha-1 in the intercropped plots. These results are similar to those reported by Randhawa et al. and Alom et al. that sole maize was significantly superior to maize + cowpea intercropping treatments. Likewise, according to Yilmaz et al., the highest yield was achieved from sole maize compared with its combination with groundnut and soybean. Crop competition for site resources has been cited as probably the main reason for reduction in yields typical of mixed culture treatments.

Performance of cowpea landraces when intercropped with maize showed significant (P≤.05) difference between them on the weight of 100 - seeds parameter (Table 3). The data showed that Landrace 2 (Black colour, Figure 1) was superior (P≤.05) compared with the other landraces. In maize however, with the exception of grain weight ear-1 and grain yield ha-1 which were not significantly (P≤.05) different, the other attributes of maize showed significant (P≤.05) differences when intercropped with cowpea landraces compared with sole maize (Table 4). The observed differences among maize grown in mixed culture with cowpea landraces is ascribed to crop competition and intrinsic differences in the ability of different cultivars to access growth resources and compete with associated crops. Similar cowpea landrace differences in yield have previously been reported in Kraslinskoff et al. in cowpea – maize mixed cultures, and crop competition was reported as possibly the main reason for reduction in crop yields. In line with this finding, Khieroar and Patra, reported that yield of cowpea during intercropping with maize was reduced due to lower amount of solar radiation received. This is because crops with C4 photosynthetic pathways such as maize have been known to be dominant when intercropped with C3 crops like cowpea. The reduction in seed yield by intercropping could be due to interspecific competition and depressive effect of maize, as C4 species on cowpea as C3 crop.

The results showed that there was significant (P≤.05) difference in the effect of intercropping system on land productivity potential or land equivalent ratio (LER) as indicated in Table 5. On the one hand, partial land equivalent ratio (LERp) of cowpea ranged from 0.87 in maize grown in mixture with cowpea landrace 2 (L2) to 1.25 in maize grown with cowpea landrace 1 (L1). Maize LERm was greater than cowpea LERp, indicating that maize is the dominant species. This result is in line with most other field studies reported in Mukhala, Tsubo, and Ogindo. On the other hand, partial land equivalent ratio (LERp) of cowpea ranged from 0.69 in L1 to 1.27 in L2. Additionally, total land equivalent ratio (LERp) ranged from 1.64 in L2 to 1.94 in L1. These findings are similar to those of Ijoyah et al. and Workayehu. Regardless of cowpea landraces, LERp values were all greater than 1 (i.e. 1.64 to 1.94), implying a significant yield advantage for the intercropping system. In other words, 64 to 94 % more land would have been required if the component crops were planted as sole crops to obtain the same yield as obtained in the intercropped plots. This corresponds to 48.3 as percent land saved with 1.85 competitive ratio. In this study, LERp>1, an indication that intercropping is advantageous in terms of the improved use of available resources for plant growth and development.

Table 3 Effect of cropping systems and cowpea landraces on yield and yield components of cowpea (Vigna unguiculata L.) landraces in Shirimatunda, Northern Tanzania

<table>
<thead>
<tr>
<th>Cropping systems</th>
<th>Wt. of Seeds (g)</th>
<th>Wt. of 100 seeds (g.plant-1)</th>
<th>Yield (t.ha-1)</th>
<th>Shelling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sole Crop</td>
<td>250.4a</td>
<td>10.9a</td>
<td>13.5a</td>
<td>77.7a</td>
</tr>
<tr>
<td>Intercropping</td>
<td>180.9b</td>
<td>8.0b</td>
<td>9.5b</td>
<td>64.4b</td>
</tr>
<tr>
<td><strong>Landraces</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1 (Grey)</td>
<td>213.0a</td>
<td>9.9b</td>
<td>11.1a</td>
<td>68.5a</td>
</tr>
<tr>
<td>L2 (Black)</td>
<td>228.4a</td>
<td>10.3a</td>
<td>11.2a</td>
<td>68.1a</td>
</tr>
<tr>
<td>L3 (Light yellowish brown)</td>
<td>205.6a</td>
<td>8.2c</td>
<td>12.2a</td>
<td>76.6a</td>
</tr>
<tr>
<td>2 - Way ANOVA F - Statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropping System</td>
<td>15.8***</td>
<td>23.5***</td>
<td>21.8***</td>
<td>11.9***</td>
</tr>
<tr>
<td><strong>Landraces</strong></td>
<td>0.6ns</td>
<td>4.8*</td>
<td>0.7 ns</td>
<td>2.1 ns</td>
</tr>
<tr>
<td>CV (%)</td>
<td>17.2</td>
<td>13.3</td>
<td>15.8</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Values (Mean±SE, n=3) followed by dissimilar letters in a column, are significantly different. Data for 2017 and 2018 have been pooled together since they were similar

Table 4 Effect of cropping systems and cowpea landraces on yield and yield components of Maize (Zea mays L.) in Shirimatunda, Northern Tanzania

<table>
<thead>
<tr>
<th>Cropping Systems</th>
<th>Ear length (cm)</th>
<th>Rows ear-1</th>
<th>Grains row-1</th>
<th>Ear diameter (cm)</th>
<th>Total ear weight (g)</th>
<th>Grain weight Ear-1 (g)</th>
<th>Shelling (%)</th>
<th>100 seed weight (g)</th>
<th>Yield (t ha-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sole Crop</td>
<td>16.9±0.4a</td>
<td>12.1±0.3a</td>
<td>33.2±1.0a</td>
<td>14.5±0.4a</td>
<td>194.4±7.1a</td>
<td>158.0±7.3a</td>
<td>78.9±2.4a</td>
<td>42.5±1.3a</td>
<td>3.5±0.2a</td>
</tr>
<tr>
<td>Intercropping</td>
<td>14.9±0.4b</td>
<td>10.7±0.4b</td>
<td>29.3±0.9b</td>
<td>12.8±0.4b</td>
<td>170.9±4.5b</td>
<td>138.8±5.4b</td>
<td>69.9±2.4b</td>
<td>37.5±1.1b</td>
<td>3.1±0.1b</td>
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<tr>
<td><strong>Landraces</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sole Maize</td>
<td>17.7±0.5a</td>
<td>12.7±0.5a</td>
<td>34.8±1.3a</td>
<td>15.2±0.5a</td>
<td>203.7±9.7a</td>
<td>165.8±11.0a</td>
<td>82.9±3.7a</td>
<td>44.6±1.8a</td>
<td>3.7±0.2a</td>
</tr>
<tr>
<td>Maize+L1</td>
<td>16.5±0.4b</td>
<td>11.8±0.4b</td>
<td>32.4±1.1b</td>
<td>14.1±0.5b</td>
<td>189.4±7.7b</td>
<td>154.0±9.2a</td>
<td>77.2±3.3b</td>
<td>41.5±1.4b</td>
<td>3.4±0.2a</td>
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</tbody>
</table>

Citation: Makoi J. Yield and yield components of local cowpea (Vigna unguiculata L.) landraces grown in mixed culture with maize (Zea mays L.) in vertic cambisols in the Northern part of Tanzania. Forest Res Eng Int J. 2019;3(3):88-94. DOI: 10.15406/freij.2019.03.00083
Table 5 Effect of cropping systems and cowpea landraces on the total land equivalent ratio (LER) in Shirimatunda, Northern Tanzania

<table>
<thead>
<tr>
<th>Cropping System</th>
<th>LER&lt;sub&gt;1&lt;/sub&gt;ns</th>
<th>LER&lt;sub&gt;2&lt;/sub&gt;ns</th>
<th>LER&lt;sub&gt;3&lt;/sub&gt;ns</th>
<th>%LS</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0.69a</td>
<td>1.25a</td>
<td>1.94a</td>
<td>48.25a</td>
<td>1.85a</td>
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<tr>
<td>L2</td>
<td>0.77a</td>
<td>0.87c</td>
<td>1.64a</td>
<td>38.54a</td>
<td>1.15b</td>
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<tr>
<td>L3</td>
<td>0.73a</td>
<td>1.05b</td>
<td>1.78a</td>
<td>43.66a</td>
<td>1.45ab</td>
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</table>

Conclusion

In conclusion, intercropping system in the study area improved the overall profitability compared with monocropping even though the yield of the component crops was reduced when considered separately. Generally, although yields of the component crops were lower than yield from monocropping, the crop components taken together were more productive as shown by the total land equivalent ratio (LER<sub>T</sub>), percentage land saved (% LS) and the competitive ratio (CR). It was also evident that although there was no significant difference between the cowpea landraces, yield of maize grown in mixed culture with cowpea landrace 1 was higher compared with maize grown with other cowpea landraces.

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Conflicts of interest

Author declares that there is no conflict of interest.

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