Growth, Yield and Land Use Efficiency of Corn and Legumes Grown under Intercropping Systems

Anan Polthanchee and Vidhaya Treolo-ge's

(Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand; *Department of Land Resources and Environment, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand)

Abstract: A field experiment was conducted at the experimental farm of Khon Kaen University in 2001. The objectives of this study were to investigate growth, yield and yield components of corn, peanut, soybean and mungbean under intercropping and single cropping, as well as to assess the land use efficiency. Yield and yield components of corn was unaffected by intercropping system. In legume crops; peanut, soybean and mungbean, intercropping systems reduced the leaf area and top dry weight per plant as compared with single cropping. Grain yield of peanut, soybean and mungbean was reduced by 28%, 39% and 51%, respectively, as compared with single cropping. The pod number per plant was the most affected by intercropping among the yield components. However, corn-legume intercropping increased land use efficiency by 48% to 66% depending on legume species. Corn-peanut intercropping gave the highest land use efficiency. The effects of light penetration and nutrient competition are discussed.

Key words: Area time equivalent ratio, Chlorophyll concentration, Corn, Intercropping, Land equivalent ratio, Mungbean, Nutrient competition, Peanut, Shading, Soybean.

Intercropping is one means of increasing the income of a farming community under rainfed situations as it helps in better utilization of resources and ensures higher returns per unit area and time (Roy et al., 1981). Much research has shown that there is generally a trend toward higher yield under intercropping. Even in areas where yield of the companion crop was substantially reduced, total yield was greater (Evan, 1962; Andrew and Kasam, 1975; Aggarwal et al., 1992).

The farmers in the upland area of Northeast Thailand generally cultivate corn besides sugarcane and casava. Monocropping of corn is practiced in the rainy season. A possible reason for increasing the productivity by corn-based farming would be through intercropping. The degree of the advantage of intercropping varies with the combination.

Corn grain yield was unaffected by intercropping with soybean, mungbean or peanut intercrop (Searle et al., 1981; Hiebsch et al., 1995; Chowdhury, 1993). Corn-soybean intercropping increased corn yield by 20% over single corn cropping (Nair et al., 1979). Corn grain yield increased by 15-20% when intercropped with soybean, blackgram or peanut (Singh et al., 1986). Corn-soybean, corn-mungbean and corn-peanut intercropping reduced soybean, mungbean and peanut yields as compared with sole cropping (Chui and Shible, 1984; Chowdhury, 1993; Sampet et al., 1989).

The Land Equivalent Ratio (LER) is commonly used in research on intercropping to determine land-use efficiency (Cordero and McCollum, 1979). However, the LER method is calculated based on land area without consideration of the time the field is dedicated to production. To correct this deficiency, Hiebsch and McCollum (1987) modified the LER method to include the duration of time the crop was on the land from planting to harvest. This method is known as the Area Time Equivalent Ratio (ATER).

Since component crops in an intercropping system vary in phenology, growth habit, etc, qualitative and/or quantitative effects of intercropping on productivity are likely to vary with crops. The objectives of this study were to compare growth, yield and land use efficiency of corn-peanut, corn-soybean and corn-mungbean intercropping with those of sole cropping.

Materials and Methods

This research was conducted at the experimental farm, Khon Kaen University, Thailand. The field was planted in an Oxic Paleustolls soil with sandy loam texture, 0.47% organic matter content, pH 6.28 (1:1 soil:water, pH meter), 0.016% total N (Kjeldahl method), 25.43 mg kg⁻¹ available P (Bray no. 2 extraction) and 36.27 mg kg⁻¹ exchangeable K (1 N ammonium acetate extraction). Soil moisture content at field capacity and permanent wilting point were 8.71 and 2.74 (% W/W), respectively. The plants were seeded on 15 July 2001. Corn, peanut, soybean and mungbean were harvested approximately 100, 95, 95 days and 65 days after seeding (DAS), respectively.

Seven cropping systems were designed with four replications in a randomized complete block design. Besides the single cropping of corn, peanut, soybean and mungbean, there were intercropping of corn-peanut, corn-soybean and corn-mungbean. The size of each
plot was 4 m wide and 6 m long. Corn and legumes for single cropping were planted at the same time as those for intercropping. Legume crops were planted in a row between the corn rows. The plant spatial arrangement and population densities used are shown in Table 1.

Corn recommended variety “Suwan 3”, peanut “Khon Kaen 4” soybean “KKU-74” and mungbean “Chainat 72” were used. Two weeks before seeding, dolomitic limestone at the rate of 625 kg ha⁻¹ was incorporated into the soil. Corn and legumes received a basal fertilizer of N, P and K at a rate of 23, 9 and 18 kg ha⁻¹, respectively. Soybean seeds were inoculated with rhizobium before seeding. Urea was applied to the corn at a rate of 29 kg N ha⁻¹ at 25 DAS. Weeds were controlled with a hand hoe at 15 and 30 DAS. An insecticide, Furadan 3 G, was applied to the legumes at planting to control bean flies. Furadan 3 G was applied again to the corn at 30 DAS to control stem borer. Monocrotrophos was sprayed onto the legumes at 30 DAS to control aphids, and again onto the mungbean and soybean to control the pod borer at 45 and 75 DAS, respectively.

Corn grain yields and number of cobs per plant were determined from 40 plants in each plot. The number of grains per cob and 100 grain weight were determined from 20 cob subsamples collected from randomly selected plants. For legumes, eight plants from each plot were used for dry weight and leaf area measurements. Leaf area was measured using a leaf area meter (Model No. AAC-400, Hayashi Denko Co., Ltd., Japan). The final grain yields and number of pods per plant were determined from 40 plants in each plot. The number of grains per pod and 100 grain weight were determined from 100 pod subsamples collected from randomly selected plants.

Leaf samples of legumes in single cropping and intercropping were collected at 30 days after seeding and at flowering to determine N, P and K contents. Nitrogen content was measured by micro kjeldahl procedures, P content by the wet oxidation method (Spectro-photometer) and K concentration by wet oxidation method (Frame Photometer). Again leaf samples of the trifoliate leaf at the 3rd from the top were collected at 25 and 45 DAS in mungbean and at 25, 45 and 75 DAS in peanut and soybean to determine the chlorophyll content according to the method outlined by Mackinney (1941).

Rainfall and temperature were recorded during the growing season. The moisture content of soil sampled from 0–15 cm depth were determined using a gravimetric procedure at 7 days after corn planting and weekly thereafter until harvest of legumes in single cropping and intercropping. Solar radiation was measured with a Lux Meter (Model Digicon, LX–50). Solar radiation was measured at the top of the corn canopy and it was taken as 100%. Solar radiation was also measured beneath the corn canopy (i.e., at the top of the legumes canopy by intercropping and at 60 cm above ground level in single cropping and the percentage of light penetration was calculated.

Land use efficiency was determined by calculating the Land Equivalent Ratio (LER) according to the method outlined by Mead and Willey (1980) as follows:

\[
\text{LER} = \frac{\sum_{i=1}^{n} \left( \frac{Y_i}{Y^0} \right)}{\sum_{i=1}^{n} \left( \frac{Y_i}{Y^0} \right)}
\]

where

\[
Y_i = \text{yield of crop } i \text{ in intercropping,}
\]

\[
Y^0_i = \text{yield of crop } i \text{ in single cropping,}
\]

\[
n = \text{total number of crops in the intercropping system}
\]

The area time equivalent ratio (ATER) was calculated as follows (Hiebsch, 1987):

\[
\text{ATER} = \sum_{i=1}^{n} \left( \frac{t^0_i}{t^i} \right) \left( \frac{Y_i}{Y^0} \right)
\]

where

\[
t^0_i = \text{growing period of crop } i \text{ in single cropping,}
\]

\[
t^i = \text{total growing period for the intercropping system,}
\]

\[
Y_i = \text{yield of crop } i \text{ in intercropping,}
\]

\[
Y^0_i = \text{yield of crop } i \text{ in single cropping,}
\]

\[
n = \text{total number of crops in the intercropping system.}
\]

Results

1. Rainfall and temperature

Total rainfall was about 612 mm during the growing season (Fig. 1). The highest weekly rainfall was 152 mm, received in week 10 after corn was seeded. Mean weekly maximum and minimum temperatures were in the ranges of 30 to 33°C and 23 to 25°C, respectively (Fig. 1).

2. Soil moisture content

The soil moisture contents at 0–15 cm depth of the fields for single cropping and corn–peanut, corn–soybean and corn–mungbean intercropping were maintained in an available range between field capacity and permanent wilting point during most of the growing season (Figs. 2, 3 and 4). However, single cropped plots
Table 1. Cropping systems, plant spatial arrangements and population densities.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Row-spacing (cm)</th>
<th>Intra-row spacing (cm)</th>
<th>Number of plants per hill (hill⁻¹)</th>
<th>Population density (plant ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
<td>Legume</td>
<td>Corn</td>
<td>Legume</td>
</tr>
<tr>
<td>Single corn</td>
<td>75</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Single peanut</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Single soybean</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Single mungbean</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Corn-peanut</td>
<td>75</td>
<td>75</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Corn-soybean</td>
<td>75</td>
<td>75</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Corn-mungbean</td>
<td>75</td>
<td>75</td>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 2. Soil moisture contents at 0-15 cm depth for the single peanut cropping (—■—) and corn-peanut intercropping (—■—) during the experimental period in 2001.

Fig. 3. Soil moisture contents at 0-15 cm depth for the single soybean cropping (—■—) and corn-soybean intercropping (—■—) during the experimental period in 2001.

Fig. 4. Soil moisture contents at 0-15 cm depth for the single mungbean cropping (—■—) and corn-mungbean intercropping (—■—) during the experimental period in 2001.

had a higher soil moisture content than intercropped plots for about 42 DAS in corn-peanut and corn-soybean intercropping, and for 50 DAS on corn-mungbean intercropping. Thereafter, single cropped plots had a lower soil moisture content than intercropped plots until harvest.

3. Light penetration

There was no significant difference in light penetration (%) through the corn canopy between single corn cropping (60 cm above ground) and corn-peanut, corn-soybean or corn-mungbean intercropping (top of legumes canopy) (Table 2). The light penetration through the corn canopy in corn-peanut, corn-soybean and corn-mungbean intercropping ranged from 46-73% depending on corn growth stage.

4. Yield and yield components of corn

Corn grain yields, the number of cobs per plant, the number of grains per cob, and 100-grain weight were unaffected by intercropping (Table 3). These data suggest that the competition effect for growth factors between corn and intercropped peanut, soybean or
mungbean was slight during the period when the corn and legume crops overlap.

5. 

5. Nutrient contents in legumes

At 30 DAS and at flowering, nitrogen (N) content in leaves was not significantly different between intercropping and single cropping (Table 4). Nitrogen fixation rates of the three legume crops were not measured, but the data suggest that intercropped peanut, soybean and mungbean were not competing with corn for soil N. A similar result was observed for phosphorus (P).

There was no significant difference in nutrient contents of leaves between single cropping and intercropping in peanut and soybean, but the K content of mungbean was higher in intercropped plots, than in single cropped plots (Table 4).

6. Chlorophyll content of legumes

Total chlorophyll content of leaves at 25 and 45 DAS was unaffected by intercropping in peanut, soybean and mungbean, but the chlorophyll content at 75 DAS was affected by intercropping in peanut and soybean (Table 5). The chlorophyll content in leaves under intercropping was highest in peanut, and that under single cropping was highest in soybean. The chlorophyll content of soybean was more sensitively influenced by the shading than that of peanut. The difference in sensitivity may be attributed to differences in the response to light stress.

7. Leaf area per plant in legumes

The leaf area per plant was decreased by intercropping by 33%, 21% and 24% at 30, 45 and 75 DAS, respectively, in peanut by 41%, 26% and 43 at 30, 45 and 75 DAS respectively, in soybean and by 33% and 41% at 30 and 45 DAS, respectively, in mungbean as compared with single cropping (Table 6).

8. Top total dry weight per plant in legume

Intercropping reduced the top dry weight by 36%, 47% and 49% at 30, 45 and 75 DAS, respectively, for peanut and by 48%, 45% and 48% at 30, 45 and 75 days after planting, respectively, in soybean as compared with single cropping (Table 6). In mungbean, the top dry weight was reduced by intercropping by 42% and
Table 4. Nutrient contents of leaves in peanut, soybean and mungbean at 30 days after seeding (DAS) and at flowering as influenced by intercropping.

<table>
<thead>
<tr>
<th>Cropping systems</th>
<th>N (g kg⁻¹) 30 DAS</th>
<th>N (g kg⁻¹) Flowering</th>
<th>P (g kg⁻¹) 30 DAS</th>
<th>P (g kg⁻¹) Flowering</th>
<th>K (g kg⁻¹) 30 DAS</th>
<th>K (g kg⁻¹) Flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>34.9</td>
<td>29.9</td>
<td>3.5</td>
<td>2.9</td>
<td>27.4</td>
<td>23.8</td>
</tr>
<tr>
<td>Intercropping</td>
<td>37.6</td>
<td>29.4</td>
<td>2.8</td>
<td>2.7</td>
<td>34.2</td>
<td>23.9</td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>30.6</td>
<td>30.9</td>
<td>6.14</td>
<td>2.84</td>
<td>30.5</td>
<td>19.1</td>
</tr>
<tr>
<td>Intercropping</td>
<td>33.4</td>
<td>29.5</td>
<td>5.16</td>
<td>2.91</td>
<td>35.1</td>
<td>21.6</td>
</tr>
<tr>
<td>Mungbean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>38.2</td>
<td>26.1</td>
<td>7.2</td>
<td>4.7</td>
<td>38.9</td>
<td>18.5</td>
</tr>
<tr>
<td>Intercropping</td>
<td>39.1</td>
<td>25.3</td>
<td>6.7</td>
<td>5.6</td>
<td>37.0</td>
<td>26.6*</td>
</tr>
</tbody>
</table>

* Significant at P<0.05 using LSD.

Table 5. Total chlorophyll contents of leaves in peanut, soybean and mungbean at 25, 45 and 75 days after seeding (DAS) as influenced by intercropping.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Chlorophyll concentration (mg g⁻¹)</th>
<th>25 DAS</th>
<th>45 DAS</th>
<th>75 DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>1.55</td>
<td>0.327</td>
<td>0.547</td>
<td></td>
</tr>
<tr>
<td>Intercropping</td>
<td>1.28</td>
<td>0.583</td>
<td>1.207*</td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>1.74</td>
<td>1.21</td>
<td>1.90</td>
<td></td>
</tr>
<tr>
<td>Intercropping</td>
<td>1.34</td>
<td>1.24</td>
<td>1.46*</td>
<td></td>
</tr>
<tr>
<td>Mungbean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>0.696</td>
<td>0.340</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Intercropping</td>
<td>0.533</td>
<td>0.283</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at P<0.05 using LSD.

40% at 30 and 50 DAS, respectively, as compared with single cropping (Table 6).

9. Yield and yield components of legumes
The number of pods per plant and seed yields of peanut, soybean and mungbean were affected by intercropping, but the number of seeds per pod and 100 seeds weight were unaffected (Table 7). The number of pods per plant was reduced by intercropping by 46, 57 and 58% in peanut, soybean and mungbean, respectively, and the seed yields by 28, 39 and 51% in peanut, soybean and mungbean, respectively, as compared with single cropping (Table 7).

10. Land use efficiency
The land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated to determine the effect of intercropping on land use efficiency. LER and ATER in corn-legume intercropping were 1.48 – 1.66 and 0.96–1.58, respectively. Corn–peanut intercropping gave the highest LER (1.66) and ATER (1.58) values (Table 8).
Table 6. Leaf area and top total dry weight of peanut, soybean and mungbean at 30, 45 and 75 days after seeding (DAS) as influenced by intercropping.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Leaf area (cm² plant⁻¹)</th>
<th>Top total dry weight (g plant⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 DAS</td>
<td>45 DAS</td>
</tr>
<tr>
<td>Peanut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>466.2</td>
<td>766.0</td>
</tr>
<tr>
<td>Intercropping</td>
<td>311.5*</td>
<td>601.2*</td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>430.4</td>
<td>570.0</td>
</tr>
<tr>
<td>Intercropping</td>
<td>250.8*</td>
<td>421.7*</td>
</tr>
<tr>
<td>Mungbean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>399.6</td>
<td>520.3</td>
</tr>
<tr>
<td>Intercropping</td>
<td>269.3*</td>
<td>308.7**</td>
</tr>
</tbody>
</table>

* *, ** Significant at P < 0.05 and P < 0.01, respectively using LSD.

Table 7. Yield and yield components of peanut, soybean and mungbean as influenced by intercropping.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Number of pods (plant⁻¹)</th>
<th>Number of seeds (pod⁻¹)</th>
<th>100-seed weight (g)</th>
<th>Seed yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>11.6</td>
<td>2.53</td>
<td>38.4</td>
<td>1,355</td>
</tr>
<tr>
<td>Intercropping</td>
<td>6.2*</td>
<td>1.80</td>
<td>39.2</td>
<td>972**</td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>33.3</td>
<td>2.56</td>
<td>20.4</td>
<td>1,605</td>
</tr>
<tr>
<td>Intercropping</td>
<td>14.2*</td>
<td>2.46</td>
<td>20.5</td>
<td>1,013*</td>
</tr>
<tr>
<td>Mungbean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single cropping</td>
<td>17.3</td>
<td>18.2</td>
<td>7.71</td>
<td>1,637</td>
</tr>
<tr>
<td>Intercropping</td>
<td>7.3*</td>
<td>16.5</td>
<td>7.78</td>
<td>796**</td>
</tr>
</tbody>
</table>

* *, ** Significant at P < 0.05 and P < 0.01, respectively using LSD.

Discussion

In this experiment corn grain yield was unaffected by legume intercrop, indicating neither competitive depression nor nitrogen transfer from the legume. Similar results have been reported by Searle et al. (1981). This is in contrast to the report by Nair et al. (1979) that corn grain yield increased by 20% when intercropped with soybean. Singh et al. (1986) also reported that corn grain yield increased by 15–20% when intercropped with soybean, blackgram and peanut. This was due to increase in NO₃ and NH₄ contents and populations of active bacteria in the corn root rhizosphere. Beet (1977) also noted that when cereals and legumes are grown together, it is usually the cereal which is least affected by the interaction.

In legume crops, leaf area and top dry weight per plant were reduced by intercropping with corn, indicating competition for growth resources between them during the overlapping period. In this experiment, light (Table 2) neither than soil moisture (Figs. 2, 3 and 4) and nutrients (Table 4) was probably the most limiting factor in corn–peanut, corn–soybean and corn–mungbean intercropping. The number of pods per plant in


Table 8. Land equivalent ratio (LER) and area time equivalent ratio (ATER) of corn-legume, intercropping.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>LER</th>
<th>ATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn – peanut</td>
<td>1.66</td>
<td>1.58</td>
</tr>
<tr>
<td>Corn – soybean</td>
<td>1.60</td>
<td>1.52</td>
</tr>
<tr>
<td>Corn – mungbean</td>
<td>1.48</td>
<td>0.96</td>
</tr>
</tbody>
</table>

peanut, soybean and mungbean were affected by intercropping but the number of seeds per pod and 100 seeds weight were unaffected. This was due to decreased leaf area and top dry weight per plant (Table 6) under intercropping. Searle et al. (1981); Johnston et al. (1969) and Mann and Jaworski (1970) have reported similar effects of intercropping on the number of pods per plant in peanut and soybean. In addition, Searle et al. (1981) noted that 100 seed weight of peanut was significantly reduced by intercropping. Subramanian and Rao (1988) reported that sorghum-mungbean intercropping reduced the number of pods per plant as well as the number of seeds per pod in mungbean. Fewer seeds per pod is probably an adaptation of the sink to a large reduction in leaf area so that grain size was maintained.

Intercropping systems significantly reduced seed yield per plant in peanut, soybean and mungbean (data not shown) as well as seed yields per hectare (Table 7). This was due to the reduced leaf area and top total dry weight per plant (Table 6) as well as the number of pods per plant (Table 7). However, seed yield per hectare was lower under intercropping systems due not only to smaller seed yields per plant but also lower plant density per unit of land area (Table 1). In this experiment, intercropping reduced seed yields by 28%, 39% and 51% in peanut, soybean and mungbean, respectively, compared with sole cropping, principally due to reduced number of pods per plant. In peanut, soybean and mungbean, the number of pods per plant was reduced by 46%, 57% and 58%, respectively. The data suggests that peanut was least affected by shading. This was probably because peanut produced a larger amount of total chlorophyll in the leaf under the shaded environment as compared with single cropping (Table 5). Larcher (1980) reported that plants adapted to shade develop extensive leaf surfaces and high the contents of chlorophyll and accessory pigments in the chloroplasts. Mungbean and soybean crops are very sensitive to shading as has been reported by Herrera and Harwood (1973).

With respect to land use efficiency, corn-legume intercropping showed a land equivalent ratio (LER) between 1.48 and 1.66. These LER indicate that 48 to 66% more land would have been used in single cropping to produce the same quantities of corn and legumes as in the intercropping systems. However, LER often overestimates the land use efficiency since it assumes that the single crop grew only once during the growth cycle. Actually, double-cropping of mungbean within the 4 months corn growth cycle is possible. If time factors are considered as in ATER (area time equivalent ratio), the corn-legume intercropping system has little advantage (Table 8). Allen and Obura (1983) reported that the maximum LER of corn-soybean intercropping in 1980 and 1981 was of 1.22 and 1.10, respectively, but the maximum ATER was 1.12 and 1.01, respectively.

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