Evaluation of Intercropping System of Maize and Leguminous Crops in the Nile Delta of Egypt

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Abstract Saving irrigation water and increasing crop productivity are critical issues in Egypt. A field experiment of intercropping system was conducted with the purpose of minimizing evaporation from soil surface in the Nile Delta. Monoculture of maize, cowpea, soybean, intercropping of maize/cowpea, and maize/soybean were compared. In intercropping plots seeds of maize and leguminous crops were sown on the same ridge alternately by zigzag planting. Leaf area index (LAI) of canopies, SPAD value of maize leaves, biological yield and grain yield, water use efficiency (WUE), and land equivalent ratio (LER) were investigated. Establishment of cowpea plants was extremely poor which indicated that cowpea was not suitable to the highly compacted soil. Canopy of maize/soybean had higher LAI (3.2) than maize-mono (1.7), which is a positive indicator to minimize the evaporation. SPAD values of maize leaves increased by intercropping with leguminous crops. However, grain yield of maize and soybean decreased by 34% and 48%, respectively, when intercropped. Although the production of individual crop was reduced by intercropping, the system slightly improved the total land productivity (LER = 1.16). WUE of maize/soybean was similar to maize-mono, but higher than WUE of soybean-mono plot. Considering maize as a main crop, since intercropping with soybean covered soil with higher LAI and improved LER, the zigzag intercropping system has possibility to reduce evaporation and maintain the crop productivity especially for the small scale farmers in the Egyptian Nile Delta.

Key words: Cowpea, Evaporation, Land equivalent ratio, Leaf area index, Soybean, Water use efficiency

Introduction

Saving irrigation water and increasing crop productivity in limited cultivation area is critical issue in Egypt where agriculture is nearly 100% depending on irrigation. The climate of Egypt is classified as arid and semi-arid to desert. Mean annual rainfall is usually less than 80 mm, except the coastal area, even though evaporation rate is very high (El-Nahrawy, 2011). Thus, it is necessary to establish cropping methods to minimize the loss of irrigation water from the field, e.g. to reduce the water evaporation from the soil surface. One possible approach to minimize the evaporation is to cover the soil surface by intensive intercropping system so that crops use the water for transpiration instead of evaporation of soil surface. However, the effects of intercropping on water use have received less attention than the effects on nutrient uptake, and so far there is little evidence of beneficial effect (Willey, 1979).

Maize (Zea mays L.) is one of the main summer crops in Egypt for both human consumption and animal feeds, while production of soybean [Glycine max (L.) Merr.] is very limited. The self-sufficient percentage of soybean in Egypt is extremely low and estimated as 3.0% (FAO, 2011) although it is an important crop to produce cooking oil in Egypt, and the average grain yield per unit area in Egypt is at the highest level in the world (FAO, 2013).

Cowpea [Vigna unguiculata (L.) Walp.] is also one of the most important leguminous crops in Egypt, and grown as vegetables and as dry seeds for both human and animals. However, the production of cowpea is limited as well since maize and rice are most popular crops to grown in summer season. Intercropping system of these leguminous crops with maize crop is one of the possibilities to introduce soybean and cowpea production to farmers.

There are many studies which investigated the benefits of intercropping systems planted with rows, e.g. strip intercropping (Gao et al., 2009; Ouda et al., 2007;
Abdel-Gawad et al., 2011; Tsujimoto et al., 2013). However, we tried a new intercropping method by “zigzag” planting system to minimize the evaporation from the soil surface, so that the crops intercropped with maize would be able to use the water. Therefore, the objectives of this study were to evaluate the zigzag intercropping system for production of maize, and leguminous crops (cowpea and soybean) by biological yields, grain yields, and water use efficiency (WUE). The land equivalent ratio (LER) was also considered in the study as it is the most general useful single index for expressing the yield advantage of intercropping system (Willey, 1979; Mead and Willey, 1980; Willey and Rao, 1980), and expresses the relative land area required as sole crops to produce the same yield as intercropping.

Materials and Methods

Experimental site

The field experiment was conducted in June to October, 2012 in the experimental field of Sakha Research Station (31°05'58" N and 30°55'19"E), Agriculture Research Center in Arab Republic of Egypt. The soil is classified as Vertisols. The bulk density of the soil in the experimental field ranged from 1.54 to 1.73 g cm⁻³ in 0 to 80 cm deep from the soil surface (Table 1). The climate of the area belongs to the arid climate, characterized by very hot dry summer (Fig. 1). Figure 1 shows that the field did not receive any rainfall during the experiment (from June to September), and the total precipitation in 2012 was 146 mm.

Intercropping treatment and field layout

Five different crop combinations, maize monoculture (MM), cowpea monoculture (CM), soybean monoculture (SM), maize and cowpea intercropping (MCI), and maize and soybean intercropping (MSI), were compared. In intercropping plots, seeds of maize and leguminous crops were sown on the same ridge with alternative “zigzag” manner (Fig. 2). The distance between the ridges was 80 cm, and between plants within a row was 25 cm. The size of each plot was 5.6 m × 15 m, and arranged by complete randomized block design with 3 replications, which made total area of 1260 m².

Crop management

In total 274 kg of nitrogen (N), 55 kg of phosphorus (P₂O₅) and 57 kg of potassium (K₂O) per ha were applied to the field. All amount of P₂O₅ was applied by single super phosphate in land preparation. One fifth of N and all K₂O fertilizer were applied just before sowing by urea and potassium sulfate, respectively. Two third of N fertilizer were applied as urea at 1st and 2nd irrigation time.

Varieties used in this study were maize: Three Way Cross 324, cowpea: Kaha No. 1, and soybean: Giza 111. Seeds of all crops were sown on June 6, however, seeds of cowpea and soybean were re-sown on June 21 and June 24, respectively, due to the poor germination. Two to 3 seeds per hill were sown, and thinned to leave 1 plant to grow per hill after the germination was confirmed.

Table 1. Soil physical characteristics of the experimental field.

<table>
<thead>
<tr>
<th>Soil profile (cm)</th>
<th>Horizon</th>
<th>Color</th>
<th>Structure</th>
<th>Bulk density (g cm⁻³)</th>
<th>Water content (v/v)</th>
<th>Soil hardness index (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4.5</td>
<td>Ap1</td>
<td>5YR 4/1</td>
<td>Granular</td>
<td>1.54</td>
<td>0.12</td>
<td>23.0</td>
</tr>
<tr>
<td>4.5 - 29.5</td>
<td>Ap2</td>
<td>5YR 3/1</td>
<td>Columnar</td>
<td>1.62</td>
<td>0.23</td>
<td>30.8</td>
</tr>
<tr>
<td>29.5 - 65.0</td>
<td>C1</td>
<td>5YR 3/1</td>
<td>Blocky</td>
<td>1.73</td>
<td>0.32</td>
<td>30.7</td>
</tr>
<tr>
<td>65.0 - 80.0</td>
<td>C2</td>
<td>5YR 3/1</td>
<td>Blocky</td>
<td>1.57</td>
<td>0.41</td>
<td>22.3</td>
</tr>
</tbody>
</table>

*Soil hardness index was measured by Yamanaka Soil Hardness Meter.*
Irrigation was applied 5 times during the experiment on June 25, July 13, July 31, Aug. 17 and Sep. 13 by furrow irrigation. The total amount of irrigated water was 618 mm.

**Parameters investigated**

Leaf area index (LAI) was measured by Plant Canopy Analyzer (LAI-2200, LI-COR, Inc.) at 3 spots on Aug. 18 to estimate the coverage of the field. On the same day leaf color value (SPAD) of maize leaves was also measured 3 times on a leaf at the middle of 3 plants by SPAD Meter (SPAD-502 Plus, Konica Minolta, Inc.).

Above-ground parts of 3 plants were sampled from each plot on Aug. 9 (blister stage of maize and beginning of pod-setting of leguminous crops), and on Sep. 19 (maturity stage of both maize and leguminous crops). Plant samples were dried in the oven at 70 °C for 72 hr for dry weight measurement.

Yield survey was conducted on Oct. 6. All above-ground plants were sampled from 1 m² in each plot, and separated into vegetative and reproductive parts, and then ears of maize and pods of soybean were investigated to obtain yield components. Grain yield was adjusted as 15% moisture content. The yield survey was carried out with only maize and soybean since cowpea plants had very poor establishment in all plots. The significance of differences in mean values was analyzed by Tukey method using software of Statistix 9 (Analytical Software, Co.).

Using the data sets of yield survey, Land Equivalent Ratio (LER) was calculated as follows (Willey, 1979):

\[
LER = \frac{L_1}{L_2} = \frac{Y_L}{YM_1} + \frac{Y_L}{YM_2}
\]

where \(L_1\) and \(L_2\) are the LERs for individual crops, \(Y_L\) and \(YM_1\) are the yields of individual crops when intercropped, and \(YM_1\) and \(YM_2\) are their yields when monocultured. Water use efficiency (WUE) was also calculated as the biological yield (WUEbio) and the grain yield (WUEgr) divided by the amount of irrigation water.

**Results**

**LAI, SPAD values, and above-ground dry weight**

Figure 3 shows LAI and SPAD values measured on Aug. 18 during blister stage of maize and pod-setting stage of leguminous crops. In the plot of cowpea monoculture (CM) canopy establishment was very poor (Fig. 3a), and there were significant amount of weeds. Maize monoculture (MM) had very low LAI with 1.72 m² m⁻², while maize/soybean intercropping plot (MSI) had 3.16 m² m⁻², which is 84% higher than that of MM plot (Fig. 3a). Soybean monoculture (SM) showed the highest LAI value. SPAD values of maize leaves were higher when intercropped with leguminous crops (Fig. 3b).

Total dry weight of above-ground plant sampled on Aug. 9 and Sep. 19 were shown in Fig. 4. Aug. 9 was in blister stage of maize and pod-setting stage of leguminous crops. Sep. 19 was in maturity stage of all crops. In both stages MM, MCI and MSI showed no significant difference in amount of dry matter production in total. However, dry matter productions of maize plant in intercropping plots were decreased, especially in maturity stage with significant difference.

**Yield, yield components, WUE and LER**

Shoot dry weight, grain yields and other parameters of maize and soybean are presented by both per area and per plant in Table 2 and 3, respectively. Grain yield of maize per unit area was significantly lower in intercrop-

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**Fig. 3.** Leaf area index (LAI) of canopies (a) and SPAD value (leaf color value) of maize leaves (b) at blister stage of maize (Aug. 18, 2012).

*Impossible to measure LAI due to poor canopy development. The error bars indicate SD (n = 3).*
ping with soybean by 34% reduction (Table 2). Grain number per ear, plant number per area, and ear number per area were also decreased by intercropping (Table 2). However, grain weight per ear was not affected by intercropping. These results suggest that the number of ear per area is the main cause of the reduction in grain yield. Shoot dry weight was also decreased by intercropping which had as same trend as data shown in Fig. 4b.

Seed yield of soybean per unit area and per plant both decreased when intercropped with maize (Table 3). The reduction in seed yield per m² was 48% which is predominantly due to pod number per plant, and also to plant number per unit area. Shoot dry weight of soybean was also decreased by intercropping as plant number decreased.

The summary of the results is described in Table 4. Sum of biological yield (shoot dry weight per unit area), grain yield, WUE_{BY} and WUE_{GT} in intercropping plots were not different from those of MM, however, were higher than those of SM. LERs of maize and soybean in intercropping system were 0.65 and 0.51, respectively (Table 4). The total LER in intercropping plot (MSI) was higher than 1 (1.16).

**Discussion**

In our study cowpea did not perform well neither

### Table 2. Yield and yield component of maize (Oct. 6, 2012).

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Plant No</th>
<th>Shoot dry wt (g)</th>
<th>Ear No</th>
<th>Ear dry wt (g)</th>
<th>Grain yield (g)</th>
<th>Shoot dry wt (g)</th>
<th>Ear No</th>
<th>Ear dry wt (g)</th>
<th>Grain yield (g)</th>
<th>Dry wt (g)</th>
<th>Length (cm)</th>
<th>Row No</th>
<th>Grain No</th>
<th>Grain wt (g)</th>
<th>Shelling rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocultured</td>
<td>7.7</td>
<td>3399</td>
<td>7.7</td>
<td>1107</td>
<td>902 (100)</td>
<td>404</td>
<td>1.0</td>
<td>145</td>
<td>118.1</td>
<td>145</td>
<td>20.3</td>
<td>12.0</td>
<td>41.7</td>
<td>500</td>
<td>114</td>
</tr>
<tr>
<td>Intercropped with soybean</td>
<td>6.0</td>
<td>2253</td>
<td>5.0</td>
<td>777</td>
<td>592 (66)</td>
<td>371</td>
<td>0.8</td>
<td>130</td>
<td>99.3</td>
<td>155</td>
<td>19.8</td>
<td>12.0</td>
<td>38.0</td>
<td>456</td>
<td>118</td>
</tr>
<tr>
<td><strong>t-test</strong></td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>*</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* indicates significant differences at P < 0.01, * indicates significant differences at P < 0.05, and n.s. indicates no significant difference at P < 0.05 by Tukey’s test.

Percentage of grain yield shown in parenthesis as the grain yield in monocultured plot 100%.

### Table 3. Yield and yield component of soybean (Oct. 6, 2012).

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Plant No</th>
<th>Shoot dry wt (g)</th>
<th>Seed yield (g)</th>
<th>Shoot dry wt (g)</th>
<th>Branch No</th>
<th>Pod No</th>
<th>Seed yield (g)</th>
<th>Seed dry wt / pod (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocultured</td>
<td>13.0</td>
<td>1125</td>
<td>462 (100)</td>
<td>86.7</td>
<td>3.8</td>
<td>153</td>
<td>35.6</td>
<td>0.23</td>
</tr>
<tr>
<td>Intercropped with maize</td>
<td>9.0</td>
<td>743</td>
<td>239 (52)</td>
<td>83.1</td>
<td>3.2</td>
<td>91</td>
<td>26.1</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>t-test</strong></td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>n.s.</td>
<td>n.s.</td>
<td>**</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* indicates significant differences at P < 0.01, * indicates significant differences at P < 0.05, and n.s. indicates no significant difference at P < 0.05 by Tukey’s test.

Percentage of grain yield shown in parenthesis as the grain yield in monocultured plot 100%.
Table 4. Summary of yield parameters (Oct. 6, 2012).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maize</th>
<th>Soybean</th>
<th>Intercropping</th>
<th>Tukey test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monocultured (t ha⁻¹)</td>
<td>Intercropped</td>
<td>Monocultured</td>
<td>Intercropped</td>
</tr>
<tr>
<td>Biological yield</td>
<td>31.0</td>
<td>22.5</td>
<td>11.3</td>
<td>7.4</td>
</tr>
<tr>
<td>Grain yield</td>
<td>9.0</td>
<td>5.9</td>
<td>4.6</td>
<td>2.4</td>
</tr>
<tr>
<td>WUEᵢᵢᵢᵢ (kg ha⁻¹ mm⁻¹)</td>
<td>50.2a</td>
<td>–</td>
<td>18.2b</td>
<td>–</td>
</tr>
<tr>
<td>WUEᵢᵢᵢᵢ (kg ha⁻¹ mm⁻¹)</td>
<td>14.6a</td>
<td>–</td>
<td>7.5b</td>
<td>–</td>
</tr>
<tr>
<td>Land Equivalent Ratio (LER)</td>
<td>0.65</td>
<td>0.51</td>
<td>1.16</td>
<td>–</td>
</tr>
</tbody>
</table>

* WUEᵢᵢᵢᵢ: Water use efficiency calculated by [biological yield in kg ha⁻¹] / [irrigated water in mm].
* WUEᵢᵢᵢᵢ: Water use efficiency calculated by [grain yield in kg ha⁻¹] / [irrigated water in mm].
* LER = Lᵣ + Lᵢᵢᵢᵢ = Yᵢᵢᵢᵢ/Yᵢᵢᵢᵢ + Yᵢᵢᵢᵢ/Yᵢᵢᵢᵢ, where Lᵣ and Lᵢᵢᵢᵢ are the LERs for individual crops, Yᵢᵢᵢᵢ and Yᵢᵢᵢᵢ are the yields of individual crops when intercropped, and Yᵢᵢᵢᵢ and Yᵢᵢᵢᵢ are their yields when monocultured.
* Values within the same column are separated by alphabet when significant at p < 0.01 (indicated as **).

in monoculture or in intercropping plots. This poor canopy establishment was probably due to highly compacted soil with high bulk density as Dauda and Samari (2002) reported that cowpea showed a low yield when bulk density increased from 1.43 to 1.60 Mg m⁻³. The bulk density of the experimental field of this study ranged from 1.54 to 1.73 g cm⁻³ (Table 1).

LAI of MSI was higher than that of MM (Fig. 4). This can be one of the advantages for MSI comparing to the MM system in order to reduce water evaporation from the soil surface. Walker and Ogindo (2003) also investigated that an intercropping system of maize and beans had denser canopy development with higher LAI values resulting in a lower soil surface evaporation, which was estimated by Ritchie model (Ritchie, 1972). Tsujimoto et al. (2013) reported that soil water potential and stomata conductance of soybean leaves indicated water stress was reduced by the shade of maize plants in maize/soybean intercropping system.

Although the SPAD values showed higher in MCI and MSI than MM plot (Fig. 3b), the growth of maize was lower in intercropping systems (Fig. 4). As a result, intercropping with leguminous crops contributed to nitrogen (N) status of maize, but there probably was another factor to restrict maize growth in MCI and MSI such as competition for light in early stage, other nutrients and soil water. It can, otherwise, be suggested that the chlorophyll contents became higher in MCI and MSI as a result of lower vegetative growth. There are several studies about N-transfer between grain legumes and nonlegumes in intercrops (Giller et al., 1991; Sawatsky and Soper, 1991; Jensen, 1996a; 1996b), and the results varied. Giller et al. (1991) studied N-transfer from beans to maize but only little amount was transferred under N limitation. Sawatsky and Soper (1991) estimated by split-root method that between 9 to 12 % of the plant N content of field pea was lost from the root system, and possibly deposited in the rhizosphere during the growth cycle. Jensen (1996a) confirmed in intercropping system that N deposited by field pea contributed about 19 % of the N in barley, especially at low rates of N-fertilization. However, Jensen (1996b) concluded that there was no evidence for N fixed by pea being transferred to barley in pea-barley intercrop field experiment of 4 years.

Not only the dry matter production but also grain yield of maize decreased by intercropping (Table 2). The maize grain yield of MSI was 66 % of MM. Allen and Obura (1983) reported corn yield by an alternate-row intercropping system and a within-row intercropping system ranged from 46 to 90 % of the corn yield by monoculture. The authors also obtained soybean yield of 52 to 54 % in intercropping compared to the monoculture. In our study the seed yield of soybean in SM was only 52 % of those of MSI (Table 3). With both maize and soybean, lower plant numbers established in intercropping plots were the direct cause of lower yield.

While, sum of both biological and grain yield as well as WUEs in intercropping plots were not significantly different from monocultured maize. The LER of 1.16 showed that the intercropping system could obtain greater productivity per unit land than monocultures of both crops. This LER greater than 1.0 gives an advantage for farmers with limited agricultural land due to limited water resources.

A review study by Morris and Garrity (1993) summarized that water-utilization efficiency by intercrops greatly exceeds that by sole crops, often by more than 18 %. However, some other studies reported that intercropping system does not always improve WUE (Ouda et al., 2007; Gao et al., 2009).

The introduction of soybean cultivation to farmers by the intercropping system also has a beneficial aspect for Egypt because soybean is an important crop which supplies high nutrition for human and live stocks.
Acknowledgements

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References


