Effect of Supplementing Inorganic Fertilizer with Organic Fertilizer on Growth and Yield of Rice-Cowpea Mixed Crop

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Abstract: With the renewed interest in mixed cropping and the increasing awareness of environmental degradation arising from high chemical inputs, this experiment was conducted to assess the effect of supplementing inorganic with an organic fertilizer on the growth and yield of rice and cowpea under the mixed cropping system. Treatments comprised six sole crops and three mixed crops, each under 100% NPK (C), 50%NPK+50% cow dung (CCD) and cow dung alone (CD). The fertilizer treatments did not significantly affect cowpea performance. However, the number of panicles per hill and the number of spikelets per panicle of rice were higher under mixed cropping than under sole cropping. On the average, rice grain yield was significantly lower under the mixed cropping than under the sole cropping. The land equivalent ratios increased under all the fertilizer treatments indicating the efficiency of the mixed-cropping system. The results of the experiment suggest that rice– cowpea mixed cropping under CCD and CD is a viable production option.

Key words: Cow dung, Cowpea, Growth, LER, Mixed crop, Rice, Yield.

Soil fertility is a crucial factor for a successful crop production. Continuous cultivation of the land has various effects on the soil properties. It has been established that continuous and improper use of inorganic fertilizers alone for intensive crop production can lead to soil degradation, environmental pollution and consequently lower yields. On the other hand, organic fertilizers have the potential to improve the chemical, physical and biological properties of the soil.

Globally, population increase and industrialization have resulted in cultivable land being decreased gradually. Arable lands are under pressure to produce for human consumption, especially in developing countries in Asia and Africa where growers own small plots of land (Awal et al., 2006). In order to meet up production these farmers need not only increase production, but also the ability to grow multiple crops on the small lands available to them. The abundant radiation available over the tropics and subtropics gives an opportunity to increase its use for better crop production. Mixed–species cropping, which has been seen as a promising technique to develop sustainable farming systems (Altieri, 1999), is one such cropping system that can be utilized.

Mixed cropping is an age-old, widespread practice in the warmer climates of the world (Agboola and Fayemi, 1972; Searle et al., 1981), especially the tropics (Willey, 1979). The method allows maximum benefit to be derived from natural resources available for production. Total grain and plant-nitrogen yields can often be increased by intercropping legumes with non-legumes (Barker and Blamey, 1985; Singh et al., 1986). Most farmers in developing countries who have adopted this low-input system have done so principally for climatic and socio-economic reasons (Okigbo and Greenland, 1976). Although agricultural research originally focused on sole cropping and ignored the potential of intercropping (Willey and Osiru, 1972), there has been a gradual recognition of the value of this type of cropping system (Blade, 1992). Growing interest in mixed cropping in developed countries (Ofori and Stern, 1987) stems from an increasing awareness of environmental degradation arising from high chemical inputs (Nielson and Mackenzie, 1977), and gives rise to a search for ways to reduce modern agriculture’s over-dependence on fertilizers, manufactured mainly with use made of fossil energy.

In sub-Saharan Africa, cow dung is one of the potential sources of organic manure. Its nutrient release to crops is slow, but the residual effect appears to be higher than that of manure from other livestock species (Karbo et al., 1999). Although cow dung has other competitive uses in this region (e.g. for cooking fuel), it is also used by farmers
for crop production. Its intensive use and in combination with inorganic fertilizer may go a long way to increase food production and sustain soil health in this region. In Africa, mixed cropping has been practiced over the years with most staple foods such as maize, cassava and sorghum with legumes like cowpea which, are cheap sources of protein in this region, but rice which is fast becoming a staple diet in most African homes has not received much attention under the mixed cropping system.

Few studies have focused on rice–cowpea mixed cropping under nitrogen fertilizer and different plant populations (Okereke and Ayama, 1992; Oroka and Omoregie, 2007). Considering the negative effect of continuous use of inorganic fertilizer alone for intensive crop production and the positive effects of organic fertilizers on the soil, the objective of this experiment is to assess the productivity of rice and cowpea under cow dung manure alone or in combination with inorganic fertilizer on the growth and yield of the component crops under the mixed cropping system. And also evaluate the land equivalent ratios of the mixed crops.

Materials and Methods

1. Plant culture

The experiment was conducted in two cropping years from May to October 2009 and 2010 at the experimental field of the Faculty of Applied Biological Science, Gifu University (35°27’N, 136°46’E). The soil was sandy loam. Soil chemical characteristics and nutrient concentrations of cow dung used are shown in Table 1. Treatment was composed of six sole crops of rice and cowpea and three mixed crops, each under three fertilizer packages. Details of the fertilizer treatments and abbreviations are presented in Table 2. The plant materials used were rice (Oryza sativa cv Leuang Tawng) and cowpea (Vigna unguiculata (L) Walp) cv. Mitori sasage (indeterminate) in 2009 and cv. Turunashi sasage (bush-type) in 2010. The indeterminate and bush-type cowpeas were used to ascertain their effect on the rice. The cow dung was obtained from the Field Science Center of Gifu University. Its application rate was calculated based on the nitrogen content to supply nitrogen as the recommended inorganic fertilizer rate. After field preparation, cow dung was applied to the designated plots two weeks prior to sowing. Each plot size was 3 m×3 m. Intra- and inter-plant spacing of crops under sole and mixed cropping was 0.3 m×0.6 m. Rice and cowpea in mixed crops were sown at half their sole crop populations for their capacity to capture and use solar radiation and soil water. Rice and cowpea were alternated in the same row. Crops were planted in mid May in both years. The phenological stages of cowpea and rice are shown in Fig. 1. Rice was transplanted and cowpea seeds were sown direct on the same day. Half of the nitrogen and all the phosphorus and potassium were applied as basal and the other half of nitrogen was applied as topdressing during the panicle initiation stage for the rice crop. Heading date for rice was 21 and 25 August 2009 and 2010, respectively. Seed setting (R5) of cowpea started from 20 July in 2009 and 24 July in 2010. Cowpea and rice were harvested at their physiological maturity at the end of August and October, respectively in both years. Plants were cultivated under upland conditions. Irrigation was done manually to supplement rainfall as and when necessary throughout the cultivation period to prevent moisture stress to the crops. Soil moisture condition

| Property | Soil | Cow dung |
|----------|------|----------|
| pH†     | 6.3  | 8.7      |
| EC† (mS cm⁻¹) | 0.10 | 1.93 |
| Total N (%) | 0.11 | 2.37 |
| Total C (%) | 1.03 | 32.14 |
| P (mg 100g⁻¹) | 0.80 | 5.64 |
| K (mg 100 g⁻¹) | 52.3 | 436.8 |
| Mg (mg 100 g⁻¹) | 2.7 | 95.8 |
| Ca (mg 100 g⁻¹) | 24.2 | 358.8 |

†, pH and EC were measured in the extract of cow dung in distilled water [1:20 (w/v) on dry weight basis].

| Treatment | Abbreviation |
|-----------|--------------|
| 100% NPK  | C            |
| 50% NPK+50% cow dung | CCD |
| Cow dung only (12t ha⁻¹) | CD        |

100% NPK for sole rice and mixed crops– 50 N, 130 P₂O₅, and 80 K₂O kg ha⁻¹. 100% NPK for sole cowpea– 30 N, 150 P₂O₅, and 100 K₂O kg ha⁻¹.

![Fig. 1. Phenological stages of cowpea and rice used in the experiment.](image)

- ●: Seeds sown. △: Flowering stage (R2). ◇: Pod formation (R3). ♡: Seed set (R5). →: Maturation.
- ○: Transplanted. ▲: Panicle initiation. ♦: Start of heading. ---→: Flowering to Maturation.
was favorable throughout the cultivation period. All other agronomic practices were undertaken as required. The experiment was laid out in a randomized complete block design and replicated thrice.

2. Measurements

Initial soil analysis was done by taking representative soil samples (April 2009) from the entire experimental area (0–15cm depth) and mixed to form a composite sample. Total carbon and nitrogen were determined by the dry combustion method using an automatic high sensitive NC analyzer (Sumigraph Model NC-800, Shimadzu Corporation, Japan). Exchangeable cations (Ca\(^{2+}\), Mg\(^{2+}\), K\(^{+}\)) were determined with an Inductive Coupling Plasma Atomic Emission Spectrometer (ICP-AES) (JEOL Leeman PS-1000UV, HITACHI P-4010) after extraction with 1N ammonium acetate (pH 7.0). Available phosphorus was determined colorimetrically (HITACHI U-1000) according to Bray and Kurtz (1945) and Murphy and Riley (1962).

Data sampling started six weeks after planting and continued till harvest. Relative chlorophyll content (SPAD value) of both crops was measured with a chlorophyll meter, model SPAD-502 (MINOLTA CO. LTD, JAPAN) on 10 randomly selected youngest and fully expanded leaves during the post-flowering and vegetative stages of the cowpea and rice respectively. Sampling for leaf area index (LAI) was done during the full pod and peak vegetative stages of cowpea and rice respectively with a plant canopy analyzer (LAI-2000 LI-COR, INC., USA). Photosynthetically active radiation was measured multiple times above and below the canopy during the full pod and peak vegetative stages of cowpea and rice respectively with a quantum light sensor (3668i6 QUANTUM LIGHT 6 SENSOR BAR) connected to (3415FX LIGHT SENSOR READER, SPECTRUM TECHNOLOGIES, INC.) and averaged (2010 only). At harvest, plant shoots were cut at soil level and oven dried at 80°C for 48 hours before weighing dry matter. For each crop, five plants per plot were harvested for yield and yield component analysis. All other observations on yield parameters of component crops were recorded using standard procedures. The land equivalent ratio (LER), which provides an all-other-things-being equal measure of the yield advantage obtained by growing two or more crops as a collection of separate monocultures (Gliessman, 2007), was used to analyze the efficiency of the mixed-cropping system as follows:

\[
LER = \frac{Y_{mr} + Y_{mc}}{Y_{sr} Y_{sc}}
\]

Where \(Y\) = yield, subscripts ‘r’ and ‘c’ refer to rice and cowpea respectively, in either sole (s) or mixed (m) cropping. \(LER > 1.0\) indicates yield advantage of the mixed cropping; \(<1.0\) indicates lack of advantage of the mixed cropping on yield. Weather data for the production period were obtained from Gifu weather station.

3. Statistical analysis

All data collected were subjected to the analysis of variance (ANOVA) appropriate to the design by the use of GENSTAT statistical package. Differences between means were determined by the least significance difference (LSD) method.

Results

1. Weather condition

The prevailing weather conditions during the period of the research are presented in Table 3. Mean monthly temperature in both 2009 and 2010 did not vary much except those of August and September which were slightly higher in 2010 than in 2009. Rainfall during the growth stage was higher in 2010 than in 2009. September in 2009 was drier than in 2010 due to low rainfall. On the whole 2010 was wetter than 2009.

| Year | Month | Maximum temp (ºC) | Minimum temp (ºC) | Mean temp (ºC) | Total rainfall (mm) | Mean relative humidity (%) |
|------|-------|-------------------|-------------------|---------------|--------------------|--------------------------|
| 2009 | May   | 25.2              | 14.9              | 19.8          | 157.5              | 59                       |
|      | June  | 28.5              | 19.0              | 23.4          | 257.5              | 62                       |
|      | July  | 30.4              | 23.2              | 26.2          | 303.0              | 75                       |
|      | August| 32.0              | 23.7              | 27.1          | 171.5              | 66                       |
|      | September | 29.0          | 19.8              | 23.9          | 67.5               | 63                       |
|      | October| 25.6             | 13.9              | 18.4          | 163.5              | 61                       |
| 2010 | May   | 24.3              | 13.6              | 18.7          | 281.5              | 57                       |
|      | June  | 28.7              | 19.9              | 23.9          | 325.5              | 66                       |
|      | July  | 32.4              | 24.2              | 27.8          | 385.5              | 69                       |
|      | August| 34.1              | 26.1              | 29.5          | 115.5              | 67                       |
|      | September | 30.9          | 21.9              | 25.9          | 261.0              | 63                       |
|      | October| 25.8             | 15.3              | 19.2          | 177.5              | 65                       |

Source: Gifu weather station.
2. Growth of cowpea and rice crops

In both 2009 and 2010, treatments had no significant effects on cowpea height. Mean cowpea height in 2009 was 108.7, 128.9, 113.4 cm in sole crops and 136.1, 131.0, 117.7 cm in mixed crops under C, CCD and CD, respectively. In 2010 mean height was 65.0, 63.7, 56.7 cm in sole crops and 66.0, 64.1, 64.8 cm in mixed crops under C, CCD and CD, respectively. The difference in plant height between years is due to the difference in cultivars of cowpea. SPAD for cowpea in 2009 was significantly greater for C and CCD than CD in sole crops (Table 4). Mixed crops were of the same greenness. SPAD of CD in sole crop was significantly less than its mixed crop counterpart. In 2010 there was no difference. In 2009 no significant effects were observed in rice crop plant height (Fig. 2). In 2010, rice plant height in both sole and mixed crops under CD was lower than that in C and CCD treatments (Fig. 3). No significance was observed between the cropping systems. In 2009 tiller numbers were higher under C than CCD and CD (Fig. 4). There was no difference between the mixed crops. In 2010 tiller numbers under C were significantly greater than under CD in the sole and mixed crops. Between the cropping systems, C and CD in mixed were significantly more than their sole counterparts (Fig. 5). The association of rice with cowpea did not negatively affect its capacity to tiller in both years with the exception of the fertilizer treatments imposed.

### Table 4. SPAD for rice and cowpea.

| Crops | Fertilizer | 16 July 2009 | 28 July 2010 |
|-------|------------|--------------|--------------|
|       |            | Sole       | Mixed      | Sole       | Mixed      |
| Cowpea | C          | 51.7 a    | 52.2 a    | ns         | 49.8 a    | 50.0 a    | ns         |
|        | CCD        | 51.3 a    | 51.9 a    | ns         | 49.9 a    | 51.3 a    | ns         |
|        | CD         | 46.8 b    | 52.6 a    | *          | 47.9 a    | 50.6 a    | ns         |
| Rice   | C          | 37.3 b    | 37.5 a    | ns         | 33.1 ab   | 35.3 a    | **         |
|        | CCD        | 40.5 a    | 38.0 a    | ns         | 33.5 a    | 33.9 b    | ns         |
|        | CD         | 37.5 b    | 37.6 a    | ns         | 32.1 b    | 32.6 c    | ns         |

The same letter indicates no significant difference among fertilizer treatments in a cropping system, † significant difference between cropping systems (**1%, * 5%; ns – non significant). Interactions between fertilizer treatments and cropping systems were not significant in both crops on both dates.
greater than CCD and CD. Under CCD, significant difference was observed between the sole crop and its mixed crop counterpart.

Light transmission rate (LT) was high in the sole rice followed by the mixed crop and sole cowpea (Table 7). Since rice needs light to tiller effectively, the high tillering in the mixed cropping could be attributed to the moderate light transmitted through the mixed crop canopies as well as availability of other resources. No difference was observed in LT and extinction coefficient (k) among the fertilizer treatments, but LT and k differed among cropping systems. The high light transmission in the sole rice could be attributed to its small LAI and k. LAI of sole cowpea and mixed crop was virtually the same, but k was higher in the sole cowpea than mixed crops, this could be as a result of the different canopy structures of the component crops. This among other factors could have facilitated the higher tiller production in the mixed crops.

C, CCD and CD with crops under CD been less green (Table 4).

LAI measured during the reproductive and vegetative stages of cowpea and rice in both 2009 and 2010 was greater under the sole cowpea and mixed crops than the sole rice crop (Table 5). The greater LAI observed under the mixed crops could be attributed to the combination of the different canopy structures of cowpea and rice. Above ground biomass production is presented in Table 6. No significant difference was observed among fertilizer treatments and cropping systems were not significant on both dates.

Table 5. Leaf area index of sole and mixed cropping systems.

| Fertilizer | 28 July 2009 | 7 August 2010 |
|------------|--------------|--------------|
|            | Cropping system | Cropping system |
|            | Sole rice | Sole cowpea | Mixed crop | Sole rice | Sole cowpea | Mixed crop |
| C          | 4.49 a | 5.63 a | 4.87 a | 3.98 b | 5.78 a | 5.72 a |
| CCD        | 4.91 a | 5.25 a | 5.38 a | 3.86 b | 5.36 a | 5.88 a |
| CD         | 4.10 b | 6.30 a | 5.25 a | 3.86 c | 5.31 b | 5.96 a |

The same letter indicates no significant difference between cropping systems at 5% LSD. Interactions between fertilizer treatments and cropping systems were not significant on both dates.
Yield of cowpea and rice crops

Yield and yield components of cowpea are presented in Table 8. In 2009 cowpea crops showed no significant differences in pod and seed number, 100-seed weight and yield among fertilizer treatments and between cropping systems. In 2010, seed number per pod and 100-seed weight did not differ significantly among fertilizer treatments. Pod number and yield per square meter differed significantly between their sole and mixed crop counterparts. The significant differences in pod numbers...
Amoah et al.—Organic Fertilizer Effect on Rice–Cowpea Cropping

between the sole and mixed cropping could be attributed to the shade effect of tall rice on the short cowpea, which might have affected the pod production and development under the mixed cropping. The low seed yield and low mixed crop to sole crop yield ratio (M/S) in 2010 is attributed to the genetic characteristics of the cultivar used.

Rice panicle number per square meter in 2009 did not differ significantly among the fertilizer treatments in the sole crops (Table 9). Panicle numbers in the mixed crops were significantly higher under C than CCD and CD and significantly lower under CCD and CD in the mixed crop than their sole crop counterparts. The decrease in panicle numbers in the mixed crops under CCD and CD could be due to lower number of panicles per hill, as the relative differences between the sole crop and their mixed crop counterparts were less than 1.0 compared with that under C. In 2010, panicle numbers under C were significantly higher than under CD in both sole and mixed crops. Panicle numbers under C and CD in the mixed crops were significantly higher than in their sole counterparts.

Spikelet number per panicle under C in 2009 were significantly lower in the mixed than its sole counterpart. In 2010, no significant difference was recorded among the fertilizer treatments in both sole and mixed crops. Spikelet numbers per panicle under CCD and CD in the mixed crops were significantly higher than in their sole counterparts. Spikelet number per square meter in 2009 did not differ significantly among fertilizer treatments in both sole and mixed crops. Between the cropping systems, spikelet numbers under C and CCD in sole crops were significantly higher than in their mixed counterparts. This difference may be attributed to the lower numbers of spikelets per panicle. Under CD in sole and mixed crops spikelet numbers did not differ significantly. In 2010, significant differences were observed among fertilizer treatments under sole and mixed cropping systems as well as between the cropping systems. In the sole crops, the number of spikelets per square meter under C was greater than under CD and in the mixed crops; spikelet number under C was greater than under CCD and CD. These differences could be as a result of lower panicle production. The percentage ripened grains in 2009 was higher in sole crops than in mixed crops; spikelet number per panicle under CCD and CD in the mixed crops were significantly higher than in their sole counterparts.

Table 9. Yield and yield components of rice planted sole and mixed with cowpea.

| Parameters               | Fertilizer | 2009 Cropping system | 2010 Cropping system |
|--------------------------|------------|----------------------|----------------------|
|                          | Sole       | Mixed                | M/S                  | Sole       | Mixed                | M/S                  |
| Panicle number (m⁻²)     |            |                      |                      |            |                      |                      |
| C                        | 132.7 a    | 138.6 a              | ns                   | 164.9 a    | 139.7 a              | *                    |
| CCD                      | 137.5 a    | 104.2 b              | *                    | 154.6 a    | 102.9 b              | **                   |
| CD                       | 135.7 a    | 105.2 b              | *                    | 129.4 b    | 96.0 b               | **                   |
| Spikelet number per panicle |            |                      |                      |            |                      |                      |
| C                        | 196.0 a    | 145.4 a              | *                    | 164.4 a    | 187.1 a              | ns                   |
| CCD                      | 182.2 ab   | 159.2 a              | ns                   | 154.6 a    | 191.1 a              | *                    |
| CD                       | 151.5 b    | 176.9 a              | ns                   | 158.6 a    | 195.0 a              | *                    |
| Spikelet number (m⁻²)    |            |                      |                      |            |                      |                      |
| C                        | 25971.9 a  | 20246.4 a            | *                    | 27057.2 a  | 26198.2 a            | ns                   |
| CCD                      | 25115.9 a  | 16425.3 a            | **                   | 24374.3 a  | 19563.1 b            | *                    |
| CD                       | 20120.6 a  | 18307.1 a            | ns                   | 20576.1 b  | 18656.2 b            | ns                   |
| % Ripened grains         |            |                      |                      |            |                      |                      |
| C                        | 83.0 a     | 53.9 a               | **                   | 75.1 a     | 79.9 a               | ns                   |
| CCD                      | 66.5 b     | 64.2 a               | ns                   | 78.5 a     | 77.4 a               | ns                   |
| CD                        | 83.5 a     | 63.6 a               | ns                   | 79.2 a     | 79.5 a               | ns                   |
| 1000 grains weight (g)   |            |                      |                      |            |                      |                      |
| C                        | 22.2 a     | 22.1 a               | ns                   | 23.0 a     | 23.5 a               | ns                   |
| CCD                      | 22.3 a     | 21.8 a               | ns                   | 23.1 a     | 23.1 a               | ns                   |
| CD                        | 22.4 a     | 21.3 a               | ns                   | 22.8 a     | 22.9 a               | ns                   |
| Grain yield (g m⁻²)      |            |                      |                      |            |                      |                      |
| C                        | 478.1 a    | 246.7 a              | *                    | 466.0 a    | 434.5 a              | ns                   |
| CCD                      | 372.7 a    | 232.3 a              | *                    | 444.4 ab   | 348.7 b              | *                    |
| CD                        | 377.9 a    | 261.3 a              | ns                   | 372.1 b    | 341.4 b              | ns                   |

The same letter indicates no significant difference among fertilizer treatments in a cropping system, † significant difference between cropping systems (* 5%; ** 1%; ns – non significant). Interactions between fertilizer treatments and cropping systems of spikelet number per panicle and % ripened grains in 2009 were significant at 5% level. Those of other parameters were not significant in both years.
mixed crop counterparts as well as among the various fertilizer treatments in the mixed crop. 1000-grain weight of rice crops did not differ between the sole and their mixed crop counterparts and among the fertilizer treatments imposed in both years (Table 9).

Grain yield per square meter of rice was significantly lower under the mixed cropping than under the sole cropping (Table 10). In 2009, grain yield per square meter did not differ significantly under C, CCD and CD in the sole and mixed crops. However between the cropping systems grain yields were greater under C and CCD in the sole than their mixed crop counterparts. In 2010, grain yield under C was significantly higher than under CD in both sole and mixed crops. Grain yield did not differ significantly between the sole crops and their mixed crop counterparts under C and CD. Yield under CCD in the sole crop was significantly higher than its mixed crop counterpart. In the mixed crops grain yields under CCD and CD did not differ significantly.

4. Mixed cropping advantage

Though grain yield of rice and seed yield of cowpea per square meter were lower under the mixed cropping, the LER of the mixed cropping irrespective of the fertilizer treatment showed that it is biologically efficient to cultivate both rice and cowpea simultaneously under the nutrient management imposed (Table 10). The LER values range from 1.40–1.53 and 1.26–1.47 signifying 40%–53% and 26%–47% increase, respectively, in productivity under mixed cropping compared with the sole cropping in 2009 and 2010. No significant differences in LER were observed among the fertilizer treatments, but component yield ratio differed between years. That of rice in 2009 was less than in 2010, which could be attributed partly to the cowpea cultivar used among other factors. The low relative yield of cowpea in 2010 could be attributed to the lower pod production of the cultivar planted in that year.

Discussion

The success of any intercropping system depends on crop compatibility. It is important to select the intercrops carefully on the basis of their mutual competition and benefit of association (Singh and Joshi, 1980). In both 2009 and 2010 the productivity of cowpea planted in association with rice and under the fertilizer treatments imposed varied little. A significant attribute of the rice in the mixed-crop was its high number of tillers, panicles and spikelets production per hill, which could be attributed to better availability and utilization of resources in the mixed cropping system in which the component crops have different growth habits and resource-use patterns compared with the sole cropping in which plants of the same species compete vigorously for the same resources. In addition, the harvest of cowpea during the reproductive stage (early heading) of rice could have contributed to the higher productivity of rice under the mixed cropping system, as a result of less plant-plant interaction and competition for resources after the harvest of cowpea. Oroka and Omoregie (2007) also reported an increase in panicle number per hill of rice intercropped with cowpea over their sole rice crops. The reduction in rice grain yield under the mixed cropping system compared with the grain yield of rice under the sole cropping system was due to the higher population of rice plants under the sole than under the mixed cropping system. Similar results have been presented by Jabbar et al. (2010), who reported a decrease in rice grain yield intercropped with forage legumes and non-legume crops compared with monocropped rice. In our research, comparison of the yield under sole cropping with that under mixed cropping with that under mixed cropping showed that the percentage decrease arising from growing both component crops simultaneously did not exceed half that of the yield in sole crops under all fertilizer treatments imposed, irrespective of the growth characteristics of the cowpea utilized, although planting density was 50% of that under the sole cropping system. Moreover, the reduction in grain yield of rice could be compensated for by the cowpea yield, although cost and benefit analysis was not conducted. This is one positive attribute of mixed-cropping where a loss or reduction in yield of a crop is compensated for by the component crop yield. Most researches on cereal-legumes mixed cropping have reported on reduced yield of component crops. However, in most cases, LER and monetary gain clearly show the advantages of mixed

| Year | Fertilizer | Rice  | Cowpea | Rice  | Cowpea | Total | Relative yield |
|------|------------|-------|--------|-------|--------|-------|----------------|
|      |            |       |        |       |        |       | Ymr / Ysr |
|      |            |       |        |       |        |       | Ymc / Ysc |
|      |            |       |        |       |        |       | LER |
| 2009 | C          | 478.1 | 169.9  | 246.7 | 148.7  | 395.4 | 0.52  |
|      | CCD        | 372.7 | 179.7  | 232.3 | 141.0  | 373.3 | 0.62  |
|      | CD         | 377.9 | 164.5  | 261.3 | 138.1  | 399.4 | 0.69  |
| 2010 | C          | 466.0 | 99.2   | 434.5 | 53.4   | 487.9 | 0.93  |
|      | CCD        | 444.4 | 97.9   | 348.7 | 47.0   | 395.7 | 0.78  |
|      | CD         | 372.1 | 91.4   | 341.4 | 47.4   | 388.8 | 0.92  |
cropping of cereals and legumes (Yunusa, 1989; Mandal et al., 1990). The results have shown that mixed cropping of rice and cowpea under CCD and CD is economically efficient, as indicated by the LER values in both 2009 and 2010. Other studies (Okonji et al., 1990; Okereke and Ayama, 1992; Okonji et al., 2007; Oroka and Omorogbe, 2007) have reported increased biological efficiency of rice-cowpea intercrops indicated by LER>1. The yield advantage of the rice-cowpea mixed cropping may be attributed to more efficient light utilization in the combination of tall rice with short cowpea. Differences in growth cycles between the crops, enabling more efficient use of available water and nutrients, can also be important (Willey et al., 1972; Webster and Wilson, 1980). Consistently, in both years, LER of cow dung alone (CD) treatment was at par with that of the other treatments, suggesting that rice-cowpea under cow dung is a viable technology. The biological efficiency (LER) obtained by cow dung treatment, could be attributed to the slow release of nutrients from the cow dung fertilizer to the crops over the production period. The growth rate was there by reduced, but the yield of mixed crops was almost the same as that of the sole crops, lessening the yield difference between sole and mixed crops, and resulting in a high relative yield of both rice and cowpea accumulating to a high total LER and being at par with the other nutrient treatments. In others words, resource utilization was efficiently channeled into productivity under cow dung fertilization over the production period.

Although some growth and yield parameters of crops under CCD and CD were reduced in comparison with crops under C, the overall results of the experiment suggest that rice and cowpea mixed cropping under CCD and CD is a viable option not only for peasant farmers, but also for the soil health and efficient land utilization based on their increased land equivalent ratios.

**Acknowledgement**

We express gratitude to the Ministry of Education, Culture, Sports, Science and Technology, Japan for the financial support without which this research would not have been possible.

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