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# Effects of NERICA - Cowpea intercropping systems on yield components and productivity of NERICA and Cowpea

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**New rice for Africa (NERICA) 1 and 2 are rice types recently introduced to upland farmers of West Africa by *AfricaRice.* Farmers in Ghana usually intercrop rice with other crops such as cowpea. The new rice types however have not been assessed for their suitability as intercropping partners of the other crops (for example, cowpea) grown in the savannah uplands of Ghana. Experiments were conducted at the upland rice experimental fields of the CSIR-Savanna Agricultural Research Institute (CSIR-SARI) in June 2008 and 2009 to determine appropriate cropping systems for cowpea and NERICA. The treatments composed of four intercropping systems, *viz*, sole cropping, strip cropping, alternate rows cropping and alternate hills cropping in a randomized complete block with three replicates. The results indicated considerable variations in yields and yield components of NERICA 1 and 2 in the presence of a companion crop, cowpea. Alternate rows of NERICA and cowpea consistently gave higher numerical cowpea grain yields, although not significantly different from the other intercrops. Yields of cowpea in partnership with NERICA 2 were generally higher than when partnered with NERICA 1. Economic analysis indicated that, given the choice of NERICA varieties, rice farmers who prefer NERICA 1 will have a better return to investment with alternate hills intercropping system while those who prefer NERICA 2 will be better off with the strip cropping system. Cowpea farmers on the other hand are better off with the alternate row cropping system.**

**Key words:** Land equivalent ratios (LER), new rice for Africa (NERICA), sustainable cropping systems, *Vigna unguiculata* L.

## INTRODUCTION

Rice is an important component of food security for upland farmers in Ghana (NAES, 2009; CSIR-SARI, 1996). In most West African countries, upland rice is produced by small and medium scale farm families. The predominant system of cultivation had been bush fallows, and slash and burn or shifting cultivation (Benneh 1993; Webster and Wilson 1980). However, long natural fallows are no longer tenable due to increasing land shortages as a result of increasing population pressures and increased demand for food (WARDA, 2008; Webster and Wilson 1980). Accordingly, continuous or permanent cultivations have emerged leading instead, to the need for increasing the cropping intensity, enhancing environmental sustainability, and the yield per unit land area

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**Table 1.** Description of treatments in cropping systems trials.

| S/N | Description of treatment |
|---|---|
| 1 | Sole NERICA |
| 2 | Sole cowpea |
| 3 | Alternate Hills of NERICA and cowpea (Alternate Hills) |
| 4 | Alternate Rows of NERICA and cowpea (Alternate Rows) |
| 5 | Strips of NERICA and cowpea (Strips) |


**Figure 1.** Treatments in the NERICA –cowpea cropping systems trial.

(Ralevic et al., 2010; Eskandari and Ghanbari 2009; Lightfoot and Noble, 2001).

In a bid to boost upland rice production in Africa, the **'**New Rice for Africa' varieties "christened" New Rice for Africa (NERICAs) were developed by the West African Rice Development Association (WARDA lately *AfricaRice*) in 2000 after a successful interspecific crossing of the two species of cultivated rice: the African rice (*Oryza glaberrima* L) and the Asian rice (*Oryza sativa* L).These varieties however, have not been assessed for their suitability as intercropping partners of the other crops grown in the savannah uplands of Ghana. Most upland rice farmers would usually intercrop their rice with a leguminous crop, mostly with cowpea. The benefits derived from such intercropping systems include the suppression of weeds and the fixation of atmospheric nitrogen into soil by the legume to improve the soil fertility and productivity (Kombiok et al*.,* 2012; Lightfoot and Noble, 2001; Comer et al., 1999).

Generally, a technology would usually be adopted by farmers if it fits well into their existing farming and cropping systems (Ojehomon et al., 2012; Agrawal, 1995; Monyo et al., 1976). The objective of this study was therefore to evaluate the suitability, productivity and sustainability of NERICA 1 and 2 in a typical upland rice-based cropping system such as upland rice-cowpea intercrop. Specifically, the study was to determine the yield and yield components of NERICA 1 (N1) and NERICA 2 (N2) and those of cowpea (CP) as influenced by different NERICA – cowpea intercrop systems. It was also to estimate land equivalent ratios (LERs) partially for the partner crop and holistically for the cropping system and assess the economic benefits of the different intercrop systems.

## MATERIALS AND METHODS

Experiments were conducted on-station at the upland rice experimental fields of the CSIR-Savanna Agricultural Research Institute (CSIR-SARI) in June 2008 and June 2009 to determine appropriate cropping system for cowpea and NERICA. The treatments composed of four intercropping systems, *viz*, sole cropping, strip cropping, alternate rows cropping and alternate hills cropping (Table 1 and Figure 1). The experimental design was a randomized complete block with three replicates. The plots were of sizes 3 × 5 m and planting distance of 40 x 40 cm for same crop when intercropped, except for sole cropping where the recommended 20 × 20 cm for rice was used. Plots were weeded twice at three and six weeks after planting before fertilizer application. First fertilizer application was 30 kg ha$^{-1}$ each of NPK, utilizing compound fertilizer NPK (15-15-15). Where N value is the percentage of elemental nitrogen by weight in the fertilizer, and the values for P and K represent the amounts of oxide in the form of $P_2O_5$ and $K_2O$. Basal application was carried out three weeks after germination followed by top dressing of 30 kg Nitrogen ha$^{-1}$ as sulphate of ammonia, six weeks after germination. Control of insect pests on cowpea was accomplished with the insecticide lambda cyhalothrin (as 'PAWA' 2.5 emulcifiable concentrate) applied at the rate of 2.5 g active ingredient ha$^{-1}$ using a backpack knapsack sprayer. Control started at initiation of racemes (flower buds) and continued at fortnightly intervals for a total of three sprays in the season (Abudulai et al., 2006).

### Collection of biological data and analysis

Data was taken on percentage germination, plant height, and number of tillers and panicles per square meter. Also data was taken on 1000 grain weight and moisture content, cowpea pod weight, rice panicle weight per plot, and grain yield of cowpea and NERICA converted to kilogram per hectare. The two year data was pooled but not compared. All data were subjected to statistical analysis of variance (ANOVA) using the GENSTAT Discovery software. Where statistical significance was measured, means were

**Table 2.** Illustrative data for the calculation of land equivalent ratio (LER).

| Monoculture | Yield in polyculture | Yield in monoculture | Partial LER | Total LER for Polyculture |
|---|---|---|---|---|
| | Y(p) | Y(m) | Y(p)/Y(m) | ∑Y(p)/Y(m) |
| .NERICA1 | 1000 | 1400 | 0.72 | = 1.36 |
| NERICA 2 | 750 | 1100 | 0.64 | |

LER= Σ {Y (pi)/Y(mi)}; Where, Y(p) is the yield of each crop or variety in the intercrop or polyculture, and Y(m) is the yield of each crop or variety in the sole crop or monoculture.

separated using the Fisher protected Least significant difference (LSD) at probability level, $P < 0.05$ (Steel and Torie, 1984).

### Land equivalent ratios (LERs)

Yancey (1994) opined that intercropping can add temporal diversity to a cropping system through the sequential planting of different crops during the same season. An important tool for the evaluation of cropping systems is the LER. LER measures the yield advantage obtained by growing two or more crops or varieties as an intercrop compared to growing the same crops or varieties as a collection of separate monocultures (Agrawal 1995; Yancey 1994; Mead and Willey 1980). The LER of the yield under the different intercropping system was calculated as

$$LER = \Sigma(Y(pi)/Y(mi)) \quad (1)$$

Where, Y(p) is the yield of each crop or variety in the intercrop or polyculture; Y(m) is the yield of each crop or variety in the sole crop or monoculture. For each crop/variety (i), a ratio is calculated to determine the partial LER for that crop/variety (for example, variety A or B in illustration), and then a sum up of the partial LERs gives the total LER for the intercrop (Table 2). A LER of 1.0 indicates no difference in yield between the intercrop and the collection of monocultures (Mazeheri et al., 2004; Agrawal, 1995; Kurata, 1986). A LER of 1.2 for example, indicates that the area planted to monocultures will need to be 20% greater than the area planted to intercrop for the two to produce the same combined yields (Okigbo and Greenland 1976; Herrara et al., 1974; Laster et al., 1972). Thus, a total LER greater than 1.0 indicates the presence of positive interferences between the varieties or crop components of the mixture (Venkatswarlu et al., 1979; Andrews et al., 1976).

### Economic analysis

Economic analysis also provided additional information about the financial implications of the trials. Agricultural production in the study area is dominated by smallholders (Kombiok et al., 2011; NAES, 1993). As such the value of capital investment is minimal or negligible. The production system is labour intensive and all the inputs applied in the system are variable (Table 8). The charges of the labourers include the equipment and tools (tractor, plough, cutlasses, hoes, boots etc) they use and their work effort. In the economic analysis of the trials in this study, partial budgets reflecting the practices of farmers in the study area were constructed for each treatment (Ojehomon et al., 2012; CYMMYT, 1988).Given the arguments made earlier, the partial budget also reflects the complete budget for the production systems. Key indicators estimated were profit and benefit-cost ratio (Saleem et al., 2000; Saeed et al., 1999). Following Saleem et al. (2000), the total value of operations cost $(TVC)$ was estimated as the algebraic sum of the product of quantity of inputs $x_i$ used and their respective market prices $p_i$ in Ghana cedis (GHC) (or US Dollars) as follows

$$TVC = \sum_{i=1}^{n} x_i p_i \quad (2)$$

Similarly, the total value of production $(TR)$ was also estimated as the production or yield $Q$ and the related market price $P$ (in GHC).

$$TR = Q \times P \quad (3)$$

The first indicator of the partial budget which was estimated was the gross profit $(GP)$ and is expected to be positive and if possible large. It measures the returns to operational investment without accounting for fixed cost and was estimated as follows

$$GP = TR - TVC \quad (4)$$

The next is the benefit cost ratio (BCR) which measures the unit returns to operational cost. In order words, it shows how much a farmer will receive when he or she invests 1 GHC into the proposed treatment. In percentage terms, it shows the percentage returns to investment. BCRs are expected to be above zero for reasonable returns on investment. A higher BCR of 50% or more indicates higher adoption potential for the technology (CIMMYT, 1988).

$$BCR = GP/TVC \quad (5)$$

The strategy with the highest BCR greater than one is economically desirable and ranked the highest. The values of all the cost items except land were estimated with their respective market prices. In addition to the trial results, data used for the economic analysis was obtained from the database of Statistics, Research and Information Directorate (SRID) of Ministry of Food and Agriculture (MoFA) in Ghana. Other sources included key informant interviews and existing farm household database at Savanna Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI).

## RESULTS

### Effects of NERICA / cowpea intercropping systems on yield and yield components of NERICA

The effects of four possible NERICA/Cowpea cropping systems on the yield and yield components of NERICA crops are presented in Tables 3 and 4. The number of tillers per square meter of land of both NERICA 1 and 2 was significantly ($P < 0.05$) higher in the sole cropping than in the other cropping systems, which were

**Table 3.** Yield and yield characters of NERICA 1 when intercropped with cowpea under the following different systems.

| Cropping system | Gem. % | No. of tillers /m$^2$ | Plant height, (cm) | No. of panicles, /m$^2$ | Panicles weight, (kg/ha) | Grains weight, (kg/ha) | 1000-grain weight, (g) | Moist. cont. (%) |
|---|---|---|---|---|---|---|---|---|
| Alternate hills | 96.9 | 147 | 69.0 | 105 | 4118 | 2869 | 26.39 | 9.47 |
| Alternate rows | 96.6 | 153 | 67.6 | 88 | 3689 | 2442 | 25.86 | 9.07 |
| Sole cropping | 89.2 | 300 | 72.3 | 159 | 7749 | 4504 | 28.04 | 11.03 |
| Strip cropping | 94.7 | 156 | 67.3 | 145 | 4542 | 2884 | 27.87 | 10.83 |
| $LSD_{(0.05)}$ | NS | 6.0 | NS | 47.5 | 2012.2 | NS | NS | NS |
| CV (%) | 3.0 | 9.5 | 5.7 | 19.1 | 20.0 | 27.1 | 5.6 | 14.8 |

NS, Not significant

**Table 4.** Yield and yield characters of NERICA 2 when intercropped with cowpea under the following different systems.

| Cropping system | Gem. % | No. of tillers /m$^2$ | Plant height, (cm) | No. of panicles, /m$^2$ | Panicles weight, (kg/ha) | Grains weight, (kg/ha) | 1000-grain weight, (g) | Moist. cont. (%) |
|---|---|---|---|---|---|---|---|---|
| Alternate hills | 94.9 | 150 | 66.2 | 79 | 2924 | 2089 | 28.28 | 9.83 |
| Alternate rows | 96.1 | 147 | 70.7 | 75 | 2664 | 1876 | 27.00 | 11.30 |
| Sole cropping | 91.1 | 300 | 71.7 | 138 | 7376 | 4836 | 27.26 | 10.03 |
| Strip cropping | 92.8 | 171 | 70.4 | 137 | 4493 | 2856 | 27.50 | 10.13 |
| $LSD_{(0.05)}$ | NS | 49.7 | 2.94 | 28.9 | 596.4 | 1258.3 | NS | NS |
| CV (%) | 5.4 | 13.0 | 2.1 | 13.4 | 6.8 | 21.6 | 5.3 | 22.3 |

NS, Not significant

statistically similar. For NERICA 1, the number of panicles per square meter was significantly ($P < 0.05$) higher in the sole cropping system compared with the alternate hills and rows. In respect of the number of panicles, no significant differences ($P < 0.05$) were detected between the sole and strip cropping systems. Panicle weight per hectare was highest in the sole and lowest in the alternate rows cropping system. However, there were no significant differences ($P< 0.05$) detected among the cropping systems in percentage germination, grain yield, 1000-grain weight and percentage moisture content.

For NERICA 2, plant height was similar and higher in the sole cropping system, alternate rows and strip than in the alternate hill cropping systems (Table 4). The number of panicles per square meter was similar and higher in the sole and strip than in the other cropping systems. Similarly, panicle weight was higher in the sole and strip cropping systems than in the other systems. Grain yield was higher in the sole than in the other cropping systems, which were statistically similar. There were no significant differences among the cropping systems in percentage germination, 1000-grain weight and percentage moisture content (Table 4).

### Effects of NERICA / cowpea intercropping systems on yield and yield components of cowpea

The effects of NERICA / Cowpea intercropping systems on the yield and yield components of cowpea (CP) are presented in Table 5. The percentage germination and grain yields of cowpea did not differ significantly for any of the cropping systems. However, plant height of cowpea under strip and sole cropping with NERICA 1 was significantly higher than the alternate hills and rows cropping (Table 5). Plant height of cowpea also was significantly higher under strip cropping with NERICA 2 than in the other cropping systems. Pod weight of cowpea was highest under sole cropping and lowest under strip cropping systems with NERICA 1. However pod weight of cowpea had almost the same values for all the cropping systems with NERICA 2.

### Total productivity and LERs of cropping systems under NERICAs 1 and 2

We compared both the overall productivity and LERs in cropping NERICA 1 and 2 in the different cropping systems (Tables 6 and 7). Considering productivity, sole cropping gave the highest combined numerical yields of both partners under the two NERICAs. The least overall production was alternate rows with N1 and alternate hills with N2. With N1 cropping systems, the highest total LER was recorded in the strip cropping while the least total LER was recorded in the alternate rows. With N2 cropping systems, the highest total LER was obtained with alternate rows while the least total LER was obtained with alternate hills. With both N1 and N2 cropping

**Table 5.** Yield and yield characters of COWPEA when intercropped with NERICA 1 and 2 (N1 and N2 respectively) under following different systems.

| Cropping system | Germination (%) | | Plant height (cm) | | Pods weight (kg/ha) | | Grains weight (kg/ha) | |
|---|---|---|---|---|---|---|---|---|
| | N1 | N2 | N1 | N2 | N1 | N2 | N1 | N2 |
| Alternate hills | 86.5 | 90.7 | 46.1 | 46.3 | 1211 | 929 | 822 | 640 |
| Alternate rows | 89.1 | 85.6 | 45.2 | 57.5 | 929 | 1387 | 922 | 1047 |
| Sole cropping | 88.1 | 87.6 | 58.9 | 69.4 | 1800 | 1420 | 1333 | 1149 |
| Strip cropping | 88.4 | 88.5 | 73.6 | 79.7 | 556 | 836 | 513 | 760 |
| $LSD_{(0.05)}$ | NS | NS | 9.58 | 16.19 | 526.9 | NS | NS | NS |
| CV (%) | 8.6 | 5.4 | 8.6 | 12.8 | 23.5 | 25.9 | 25.9 | 28.6 |

NS, Not significant.

**Table 6.** Total productivity and LER of cropping systems under NERICA 1.

| Cropping system under N1 | Cow pea grains weight (Kg/ha) | NERICA 1 grain yield(Kg/ha) | Total production (N1 + CP) Kg/ha | LER partial CP | LER partial N1 | LER total |
|---|---|---|---|---|---|---|
| | (Yp) CP | (Yp) N1 | | (Yp/Ym) CP | (Yp/Ym) N1 | (∑) |
| Alternate hills | 822 | 2869 | 3691 | 0.62 | 0.64 | 1.26 |
| Alternate rows | 922 | 2442 | 3364 | 0.69 | 0.54 | 1.23 |
| Sole cropping(Ym) | 1333 | 4504 | 5837 | 1.00 | 1.00 | 2.00 |
| Strip cropping | 513 | 2884 | 3397 | 0.38 | 0.64 | 1.02 |
| $LSD_{(0.05)}$ | NS | NS | | 0.183 | 0.022 | 0.014 |
| CV (%) | 25.9 | 27.1 | | 1.4 | 1.6 | 0.5 |

**Table 7.** Total productivity and LER of cropping systems under NERICA 2.

| Cropping system under N2 | Cow pea grains weight (Kg/ha) | NERICA 2 grain yield(Kg/ha) | Total production (N2 + CP) Kg/ha | LER partial CP | LER partial N2 | LER total |
|---|---|---|---|---|---|---|
| | (Yp) CP | (Yp) N2 | | (Yp/Ym) CP | (Yp/Ym) N2 | (∑) |
| Alternate hills | 640 | 2089 | 2729 | 0.56 | 0.43 | 0.99 |
| Alternate rows | 1047 | 1876 | 2923 | 0.91 | 0.39 | 1.30 |
| Sole cropping(Ym) | 1149 | 4836 | 5985 | 1.00 | 1.00 | 2.00 |
| Strip cropping | 760 | 2856 | 3616 | 0.66 | 0.59 | 1.25 |
| $LSD_{(0.05)}$ | NS | 1258.3 | | 0.022 | 0.021 | 0.031 |
| CV (%) | 28.6 | 21.6 | | 1.4 | 1.7 | 1.1 |

systems, significant differences were detected between the total LERs (Tables 6 and 7).

## Financial analysis

The results of the economic analysis are presented in Table 8. Major items included in the cost structure for rice were land, labour, fertilizers and bags. The cost structure of cowpea included land, labour, insecticides and bags. A farmer needs an estimated average of GHC 1,220.80 to invest on a hectare of rice. To produce 1 kg of rice, a farmer needs an estimated average of GHC 0.40. The cowpea farmer on the other hand needs an average of about GHC 641.29 to invest on a hectare of cowpea. Every kilogram of cowpea produced cost GHC 0.71.

The results show that NERICA rice production in general is a profitable business (Table 9). Profitability actually varies across the various treatments and varieties. The computed returns to investments for the rice production systems as shown by the benefit-cost ratios was up to 240% for NERICA 1 and up to 310% for NERICA 2. For both varieties, the most profitable treatment was sole cropping followed by strip cropping, alternate hills and then alternate rows (Table 9). Losses were recorded for cowpea production under alternate

**Table 8.** Cost per hectare of rice and cowpea in northern Ghana.

| Item | Rice | | Cowpea | |
|---|---|---|---|---|
| | **Value** | **Share** | **Value** | **Share** |
| Land (rent) | 156 | 12.78 | 97 | 15.13 |
| Labour | 852.79 | 69.85 | 536.80 | 83.71 |
| Insecticide | 0 | 0 | 3 | 0.47 |
| Fertilizer | 195 | 15.97 | | 0 |
| Bags | 17.02 | 1.39 | 4.49 | 0.70 |
| Total per ha | 1220.80 | 100 | 641.29 | 100 |
| Total per kg | 0.40 | | 0.71 | |

Value: Ghana cedi (GHC) per ha. Exchange rate: GHC 2.1 = USD 1.0.

**Table 9.** Returns to investment.

| Indicator | Treatments | | | | |
|---|---|---|---|---|---|
| | **Alternate hills** | **Alternate rows** | **Sole cropping** | **Strip cropping** | **Overall** |
| Nerica 1 | | | | | |
| Profit | 1657.88 | 1245.71 | 3305.35 | 1687.20 | 1974.04 |
| Benefit cost ratio | 1.25 | 0.96 | 2.40 | 1.29 | 1.47 |
| Nerica 2 | | | | | |
| Profit | 964.44 | 744.41 | 3802.09 | 1756.75 | 1816.92 |
| Benefit cost ratio | 0.80 | 0.62 | 3.10 | 1.45 | 1.49 |
| Cowpea vrs Nerica 1 | | | | | |
| Profit | 136.84 | 233.14 | 628.93 | -160.73 | 209.54 |
| Benefit cost ratio | 0.21 | 0.35 | 0.95 | -0.24 | 0.32 |
| Cowpea vrs Nerica 2 | | | | | |
| Profit | -0.93 | 391.011 | 489.24 | 114.63 | 248.49 |
| Benefit cost ratio | -0.001 | 0.63 | 0.78 | 0.18 | 0.40 |

hills with NERICA 2 and strip cropping with NERICA 1 (Table 9). The computed returns on investments indicate that prospective investors will lose up to 24% of their capital in strip cropping with NERICA 1. However for the profitable treatment, prospective sole cropping farmers were to expect as high as 95% profit from their investment.

## DISCUSSION

### Effects of NERICA / cowpea intercropping systems on yield and yield components of NERICA 1 and 2

The effects of NERICA/ cowpea intercropping systems on the yield components and subsequently on the yield of either NERICA 1 or 2 indicated important differences. Overall, N2 yields and productivity were higher than those of N1.This trend was backed by the data which showed that agronomic parameters such as plant height, tiller count and panicle number per square meter were higher for NERICA 2 than NERICA 1. Alternate hills with N1 and alternate rows cropping with N2 came out as the best intercrop options when growing cowpeas and upland NERICAs together. However, yields under sole cropping for both NERICAs were higher than those in the other systems. NERICA 2 performed generally better than NERICA 1 and similar findings have been reported by other researchers (Ojehomon, 2012; Oikeha et al., 2008). N1 has been shown to be relatively more drought tolerant than N2. In extreme cropping seasons with prolonged cases of intermittent or even terminal drought, given a legume–cereal intercrop, N1 will outstrip N2 in productivity. The former (N1) is also aromatic and such so-called “perfumed rices” attract premium prices in the Ghanaian and other markets (CSIR–SARI, 2009). The relatively higher yields of the NERICAs as sole crops may be explained in the light that in an environment of competition for space, sunlight and water, soil minerals among others, in most cases, growth and development would favour a cereal sole crop compared to the same cereal in a polyculture (Singh et al.,1996; Willey and Reddy, 1981; Willey and Osiru, 1972). The immediate or short term benefit of any legume-cereal intercrop is usually to optimise land productivity. Farmers also have a view of enhancing sustainability by improving soil fertility due to nitrogen fixing capacity of the legume (Paul van Mele et al., 2011; Oroka and Omoregie, 2007). This study however was unable to investigate the effects of these intercrops on soil fertility in the medium or long term.

**Effects of NERICA / cowpea intercropping systems on yield and yield components of cowpea**

The results indicated considerable increase in pod weight of cowpea with NERICAs 1 and 2 under sole cropping (1800 and 1420 kg/ha, respectively). Apart from the sole crops, the best cowpea pod yields were obtained with alternate rows with N2 (1387kg/ha) and to alternate hills with N1 (1211 kg/ha) (Tables 5 and 6). The evident explanation of this performance of cowpea with NERICAS 1 and 2 has once again, to do with size, compatibility and competition. For optimum grain yields for all partners in an intercrop, it is important for the components to be complementary and mutually beneficial to one another, for example, as in cereal–legume intercrops (Oroko et al, 2007., Keating and Carberry , 1993., Khan et al., 1984). The different components should also be compatible in terms of size so that they do not crowd out one another for space and sunlight among others (Kombiok et al., 2012; Ahlawat et al., 1985; Nyambo et al., 1982; Pathick and Malla, 1979).

Agronomic data from Tables 3 and 4 corroborated by the work of other researchers indicated that NERICA 2 was a larger plant than NERICA 1 (WARDA, 1999). It is thus apparent that given a much smaller and more compact NERICA 1, in order to optimise pod and grain weights of cowpea it will be more suitable to adopt alternate hills cropping system. However, for the relatively larger plants of NERICA 2, alternate rows cropping seemed to offer the cowpea crop a more conducive environment which saw expression in considerably enhanced cowpea grain and pod yields with this arrangement (Table 5). The influence of NERICA-cowpea intercrop on productivity of cowpea may not be as a result of relative plant sizes and compactness of NERICA alone. Compatibility needs to be explored. The combined effects of NERICA plant size and the number of rice plants bordering/surrounding any single cowpea stand are likely to influence the entire environment of the cowpea plant. The study at this stage however, is unable to decipher the relative importance of these factors in influencing cowpea growth, development and productivity.

**Total productivity and LERs of cropping systems under NERICA 1 and 2**

In evaluating the total productivity of the systems compared to one another (Table 6) for NERICA 1, alternate hills cropping produced the highest crop yields for rice and cowpea combined, together with the highest total LER (1.26) for the intercrop. For NERICA 2, alternate rows cropping system produced the highest total LER (1.30) but the combined highest crop yields of rice and cowpea was with strip cropping (Table 7). The central issue under investigation was one of suitability and sustainability of the cropping systems. Runkulatile et al.(1998), Venkatswarlu et al. (1979), Andrews et al. (1976) and other workers have pointed out that a total LER greater than 1.0 indicates the presence of positive interferences between crop components in an intercrop and is indicative of sustainability. Cropping N1 and cowpea in Alternate Hills system or cropping N2 and cowpea in alternate rows are in this light therefore optimum upland NERICA cowpea intercrop systems that may be recommended for adoption by majority of small scale farmers. Altogether, the above results further provide upland rice farmers with a variety of options in the choice of NERICA varieties to cultivate depending on the cropping system of their preference, the risk levels they wish to take (higher yielding N2 or more drought tolerant N1) and market preference of the upland rice (aromatic or not) they would want to intercrop with cowpea.

**Economic implications of treatments**

Despite the relatively higher cost of production per hectare, the cost of producing a kilogram of rice was relatively low. NERICA rice farmers therefore required less investment to produce a given volume of the rice. Among the list of cost items, labor constitutes the most important with a share of about 70% in the rice production system and about 84% in the cowpea production system. A cursory look at the results in Table 6 reveals that the sole cropping system gave a better return to investment than the other treatments (that is, both rice and cowpea production systems). By implication, intercropping cowpea with rice has a negative effect on rice profitability. However, comparing the results among the other intercrop systems which also yielded positive returns to investment, strip cropping produced higher returns in the rice production system followed by alternate hills and alternate rows, respectively. The trend was the same across the two NERICA varieties.

Cowpea also had high financial performance when cultivated under sole cropping system. Unlike rice, the alternate row intercrop system gave better returns to investment than the other treatments for both NERICA 1 and NERICA 2. Strip cropping system yielded losses for NERICA 1 but was profitable for NERICA 2. The reverse was true for alternate hills system. Outside the context of food security, the sole cropping systems have demonstrated their superiority over the other systems. The sole cropping systems have high potential to increase income and reduce poverty. However, within the context of food security where a household requires both carbohydrate and protein sources, there is the need to encourage the intercropping systems. Given the choice of NERICA varieties, rice farmers who prefer NERICA 1 will be better off with the alternate hills system while those who prefer NERICA 2 will be better off with the strip cropping system. Cowpea farmers on the other hand are better off with the alternate row cropping system.

## Conclusions and recommendations

There were considerable variations in yields and yield components of NERICA 1 and 2 in the presence of a companion crop, cowpea. Alternate rows of NERICAs and cowpea consistently gave higher numerical cowpea grain yields, although not significantly different from the other intercrops. Yields of cowpea in partnership with NERICA 2 were generally higher than when partnered with NERICA 1. The NERICAs performed better under strip cropping, producing higher grain yield per hectare and higher total LERs (1.02 when NERICA 1 was cropped and 1.25 when NERICA 2 was partnered with cowpea) but impacted negatively on the performance of the companion cowpea. Economic analysis indicated that, given the choice of NERICA varieties, rice farmers who prefer NERICA 1 will be better off with the alternate hills, while those who prefer NERICA 2 will be better off with the strip cropping system. Cowpea farmers on the other hand are better off with the alternate row cropping system.

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**Abbreviations: NERICA,** New Rice for Africa; **WARDA,** West African Rice Development Association; **N1,** NERICA 1; **N2,** NERICA 2; **LERs,** land equivalent ratios; **BCR,** benefit cost ratio.

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