Multiple cropping for sustainable and exaggerated agricultural production system

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ABSTRACT

Multiple cropping is a farming practice involving two or more crop species or genotypes growing together and coexisting for a certain period. It is getting importance as farmers intensifying land use to remain competitive and provide the increasing world demand for different crop originated products and in many subsistence or low-input/resource-limited agricultural systems on the fringes of modern intensive agriculture. By providing actual yield gains without increased inputs, or greater stability of yield with decreased inputs, multiple cropping becomes one unique route to delivering sustainable intensification. Innovations by agricultural scientists in pesticides, no-till instrumentation, rotation of legumes and grasses for tap-rooted and fibrous-rooted crops, and breeding crops tailored to specific systems and environments create intensified multiple cropping farming more successful. With this connection, the experiment was carried out to study effect of intercropping combinations (rice with four different vegetables) on land use efficiency using the Land Equivalent Ratio (LER) and total return per unit area based on benefit-cost ratio (BCR). Intercropping combinations had significant effect on LER and BCR for total return. Result showed that the lowest cost of production was found in sole rice under monoculture compared to all other cases of polyculture. But sole rice cultivation under monoculture is less profitable than the production of vegetable-rice intercropping. Vegetable cultivation along with rice crop is remunerative in both yield and economical point of view.

Key Words: Benefit-cost ratio, Land equivalent ratio, Multiple cropping, Rice, Vegetable and Yield.

I. Introduction

There are many techniques to enrich food production such as expanding arable land, increasing cropping intensity, improvement in technology, research, and extension of information to producers to improve genetics of crops, improve soil quality, eliminate or manage pests for improved yields of traditional crops (Anon, 1990). The area of world's cultivated land expanded by only 4% whiles the world's population increased by 40%world population growth. So, expanding cultivated arable land is...
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not a viable solution for producing a sustainable world food supply. Improved technology and other facilities are cost intensive. Tying all the above-mentioned techniques together revealed a promising alternative way which is multiple cropping. In order to increase and stabilize agricultural production the means that has greatly received the attention of scientists in the recent years is multiple cropping or intercropping (Zhang et al., 2010; Li et al., 2013). In this form of production practice, more than one crop is grown simultaneously or in sequence on the same piece of land (Harwood and Hiquita, 1976). There are several types of multiple cropping where two or more crops are grown in succession on the same land per year. These forms are generally known as sequential cropping (which includes double cropping, triple cropping, quadruple cropping, quintuple, sextuple, septuple etc.), intercropping (which includes strip and row intercropping) (Ghaffarzadeh et al., 1994; West and Griffith, 1992), Mixed cropping, Relay cropping. In this case second crop is sown while the first crop is near maturity. This is the most convenient and effective way of sustainable agricultural production, where growing more than one food, feed, fiber, industrial, green manure, mulch, or rotation crop on the same land area at the same period is possible (Li et al., 2009). This technique makes effective use of inputs such as soil, water, fertilizer etc. resulting increased per unit area with manifold returns to the growers. In multiple cropping system justified fertilizer recommendation and inputs use is crucial for sustainability (Sultana et al., 2015; Hossain and Siddique, 2015). Multiple cropping can be done by annual food crops, fodders, vegetables, fruit plants and perennial crops. It could enable the country to be self-sufficient in food production and export the surplus to earn foreign currency. Proper maintenance of soil fertility, minimum incidence of crop failure owing to natural calamities and biotic agents, efficient utilization of nutrients and land, diverse foods outputs and enhanced food production are ultimate achievements of multiple cropping (Iannetta et al., 2013; Powlson et al., 2011; Johnson et al., 2009; Adu-Gyamfi et al., 2007). Multiple cropping increases the potential for total production and farm profitability than monocropping (Anon, 1990; Martin et al., 1987). The uptake and mobilization of micronutrients is also influenced by intercropping, especially Fe in peanut and maize intercropping systems (Zheng et al., 2003; Zuo et al., 2003).

The increase in productivity per unit of land is one of the most important reasons of multiple cropping (Iinal et al., 2007). For assessing intercrop performance as compared to pure stand yields a method is designed. By growing mixtures and pure stands in separate plots the yields are measured and also an assessment of the land requirements per unit of yield can be determined. By this information the yield advantage of the intercrop over the pure stand and how much additional land is required in pure stand to equal the amount of yield achieved in the intercrop become clear (Kurata, 1986; Pathick and Malla, 1979). The calculated figure is called the Land Equivalency Ratio (LER). The LER is calculated using the formula \[ LER = \sum \left( \frac{Y_i}{Y_m} \right) \] 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. LER measures 1.0 means the amount of land required for \( W \) and \( Y \) grown together is the same as that for \( W \) and \( Y \) grown in pure stand (i.e. there was no advantage to intercropping over pure stands). LERs above 1.0 show an advantage to intercropping while numbers below 1.0 show a disadvantage to intercropping. For example, an LER of 1.25 tells us that the yield produced in the total intercrop would have required 25% more land if planted in pure stands. If the LER was 0.75 then we know the intercrop yield was only 75% of that of the same amount of land that grew pure stands (Agrawal, 1995; Francis and Decoteau, 1993; Kurata, 1986; Mazaheri and Oveyi, 2004; Laster and Furr, 1972). The Benefit-Cost Ratio (BCR) is a profitability index, used in the formal discipline of cost-benefit analysis (Quigley et al., 2003. A French Engineer Jules Dupuit (1848) first introduced the concept of benefit cost ratio which was further enhanced by British economist Alfred Marshall and became the basis for benefit cost ratio (Marshall and Brown, 1974). In course of time, the agricultural land is being reduced by approximately 1.0% of the total area per annum (Hussain et al., 2006) while the population is increasing by 1.24% (ERB, 2007), and hence, the demand for food grain is ever increasing. Inadequate information and research are the main reasons for low adoption of multiple cropping. With this view, the economic benefits of multiple cropping, there is a need to promote it among the farming community. The aim of the research on rice cum vegetable intercropping is to assess the suitability and profitability of multiple cropping best fitted to the resource poor farmer of Bangladesh.
II. Materials and Methods

The experiment was carried out at the Agronomy research farm of Bangladesh Agricultural University during the year 2008. The main intercropping crop species are rice (Oryza sativa) variety Surjamoni combined with four different types of vegetable crops like yard long bean (Vigna unguiculata), snake gourd (Trichosanthes anguina), white gourd (Benincasa hispida) and bottle gourd (Lagenaria vulgaris) were used as plant materials. Rice seedlings were raised in seedbed and transplanted to the main field following standard line sowing method. Seedlings of vegetables were raised in polybag and in seedbed which was prepared on the levee in between two trellises. The media was prepared mixing organic manure and compost with field soil. Healthy seeds of yard long bean, snake gourd, white gourd and bottle gourd were sown in the prepared media in polybag. The polybags were kept in a sunny and dry place. Proper water and pest management practices were done to raise good seedlings. Thirty-day-old seedlings of snake gourd, white gourd and bottle gourd and fifteen-day-old seedlings of yard long bean were transplanted. The seedlings of these vegetables were planted on the levee of rice plots and allowed to grow on trellis (bamboo made scaffold and branches of jujube) during the whole growth period, afterwards. Five different types of crop combinations, T0 = Rice only, T1 = Yard long + rice, T2 = Snake gourd + rice, T3 = White gourd + rice and T4 = Bottle gourd + rice were used as treatments. The experiment was laid out in a randomized complete block design (RCBD) having three replications. There were 49 unit plots of same size (3 x 6 m²) where Plot to plot and block to block distances were 75 cm and 100 cm, respectively. The experimental plots were fertilized with 270, 150, 120, 110 and 15 kg ha⁻¹ of urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate, respectively. The amount of fertilizers for four types of plot was calculated and the entire amount of triple superphosphate, muriate of potash, gypsum and zinc sulphate was applied during final land preparation as basal application. One-third of urea was top dressed at 15 days after transplanting (DAT) and the rest of urea was top dressed in two equal splits at 45 and 55 DAT. For vegetables, fertilization of the levee soil was done with cowdung urea, triple superphosphate and muriate of potash @ 10 kg, 100 g, 120 g and 100 g, respectively. Cowdung, TSP and MP were mixed with soil at the time of all preparation. Urea was applied in ring form at a certain distance from the base of the vegetables seedlings about 15 DAT. The plots were hand weeded in different vegetative stages. Each plot was harvested individually to estimate grain and biological yield. Total cost and returns were calculated to find out the benefit-cost ratio (BCR) and Land Equivalency Ratio (LER). Data were statistically analyzed using analysis of variance technique appropriate for randomize complete block design with plant densities split on planting dates and Duncan’s Multiple Range Test (Gomez and Gomez, 1984). (p<0.05) was employed for mean separation when F-values were significant. In case of vegetables, yield data was collected then converted to rice equivalent yield and finally subjected for economic analysis.

III. Results and Discussion

Rice yield

In rice cum vegetable cultivation, crop combination exerted significant influence on the different yield and yield attributes of rice. The highest grain yield (6.9 t ha⁻¹), straw yield (9.70 t ha⁻¹), biological yield (16.60 t ha⁻¹) and harvest index (41.87%) were observed under sole rice crop (Figure 01 and 02). The lowest grain yield (5.16 t ha⁻¹), straw yield (8.16 t ha⁻¹) and biological yield (13.31 t ha⁻¹) were observed under the treatment of bottle gourd + rice (Figure 01). In biomass production in species-diverse systems was, on average, 1.7 times higher than in monoculture (Cardinale et al., 2007).

Vegetable yield

Four types of vegetable were cultivated with rice (cv. Surjamoni) on the levee along with bamboo made scaffold and branches of jujube. All the vegetables included in the experiment were climbing type. The vegetables under study did perform well in combination of rice but different yield was obtained from several types of vegetables in the rice cum vegetable production technology. In vegetable cultivation along with rice crop, the highest vegetable yield (14.5 t ha⁻¹) was recorded from white gourd + rice crop and the lowest vegetable yield (5.5 t ha⁻¹) was received from two treatments, yard long bean + rice crop (Table 01).
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Rice equivalent yield (REY), rice grain yield, total grain yield and LER

It was highly encouraging to observe that all the vegetable crops grown on the levee of rice plot gave significantly higher total rice equivalent yields compared to the sole of rice in spite of grain yield reduction due to the above ground effect of trellis as noted earlier. The significantly highest rice equivalent yields were obtained in the treatment of Snake gourd + rice combination (7.88 t ha⁻¹) and the lowest rice equivalent yield (6.35 t ha⁻¹) was found from the treatment white gourd + rice (Table 01). Bottle gourd + rice combinations produced moderate rice equivalent yields ranging from 6 – 7.9 t ha⁻¹. The highest rice grain yield was 6.9 t ha⁻¹ in case of sole rice plot but in couple of the intercropping combinations rice grain yield was less (Table 01). After converting vegetable yield into rice equivalent yield, the total grain yield of each plot was more than the sole rice crop (6.9 t ha⁻¹). The highest value of total grain yield (13.15 t ha⁻¹) was found in the treatment of yard long bean + rice combination (Table 01). Beets (1994) demonstrated that corn and soybean intercropping in 1:1 combination gave maximum monetary return, greater total LER (equal to 1.35), and partial LERs of 0.7 and 0.65 for corn and soybean, respectively. Therefore, it seems that less competition between corn and soybean in 1:1 ratio compared other combinations resulting to equal partial LERs of greater than 0.5 (total LER>1) and greater mixture yield. Based on the LER value (Table 01), the result indicates that in all cases sole rice is less profitable than the plots provided with vegetable. The yield advantage (Total LER > 1.0) in multiple cropping compared monoculture in equal land area become more prominent. This result was similar to the findings of Kundu (2002).

Table 01. Vegetable yield and rice equivalent yield of the vegetable-rice cultivation system (Data are means ±SD of n=5 experiments)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Vegetable Yield (t/ha)</th>
<th>Rice equivalent yield (G1) (t/ha)</th>
<th>Grain yield (G2) (t/ha)</th>
<th>Total grain yield (G1+ G2) (t/ha)</th>
<th>Land Equivalent Ratio (LER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₀</td>
<td>-</td>
<td>-</td>
<td>6.9</td>
<td>6.9a</td>
<td>1a</td>
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<tr>
<td>T₁</td>
<td>5.9</td>
<td>7.675</td>
<td>5.475</td>
<td>13.15c</td>
<td>4,12b</td>
</tr>
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<td>T₂</td>
<td>6.05</td>
<td>7.875</td>
<td>5.175</td>
<td>13.05c</td>
<td>4,18b</td>
</tr>
<tr>
<td>T₃</td>
<td>11.95</td>
<td>6.35</td>
<td>5.2</td>
<td>11.55b</td>
<td>4,04b</td>
</tr>
<tr>
<td>T₄</td>
<td>9.45</td>
<td>7.1</td>
<td>5.175</td>
<td>12.275bc</td>
<td>4,10b</td>
</tr>
</tbody>
</table>

Level of significance: * Indicates significant at 1% and ** Indicates significant at 5% level of significance; T₀ = Rice only, T₁= Yard long * rice, T₂= Snake gourd * rice, T₃= White gourd * rice, T₄= Bottle gourd + rice

Economic analysis

Total cost of production: The input costs, overhead costs and total cost of production of vegetable-rice production system was assessed. It is observed that vegetable cultivation on the levee of rice plot involved on extra expenditure that was marginally higher than only rice cultivation in the control plot. On average, only rice cultivation incurred 70,647.8 BDT ha⁻¹, while vegetable–rice intercropping cultivation added extra cost of production (Table 02). Result showed (Table 02) that the lowest cost of
production (70,647.8 BDT ha$^{-1}$) was found in sole rice but in all other cases it was more. The main reason behind this is cost involvement for the production of two crop combinations.

**Table 02. Cost of production of vegetable-rice intercropping (Data are means ±SD of $n=5$ experiments)**

<table>
<thead>
<tr>
<th>Treatment combination (Crop combination × Trellis)</th>
<th>Input cost (BDT/ha)</th>
<th>Overhead cost</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Material cost</td>
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<td></td>
<td>Seed cost</td>
<td>T0</td>
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<tr>
<td></td>
<td>28000</td>
<td>58630</td>
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<td>31000</td>
<td>46750</td>
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</tbody>
</table>

**Note:**

- $T_0$ = Rice only
- $T_1$ = Yard long bean + rice
- $T_2$ = Snake gourd + rice
- $T_3$ = White gourd + rice
- $T_4$ = Bottle gourd + rice

<table>
<thead>
<tr>
<th>Treatment combination (Crop combination × Trellis)</th>
<th>Input cost (BDT/ha)</th>
<th>Overhead cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed cost</td>
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<tr>
<td></td>
<td>T0</td>
<td>30000</td>
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<td></td>
<td>T1</td>
<td>30000</td>
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<tr>
<td></td>
<td>T2</td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td>T4</td>
<td>30000</td>
</tr>
</tbody>
</table>

**Gross return:** Economic analysis showed that vegetable-rice cultivation gave higher gross return than that of sole rice (Table 03). Maximum gross return (2,80,650.00 BDT ha$^{-1}$) was obtained from the treatment combination yard long bean + rice and sole rice gave the minimum gross return (1,57,400.00 BDT ha$^{-1}$) (Table 03). Higher yield and economic returns in intercrops were also reported by Jana et al. (1999), Mandal et al. (1990), Zaman et al. (1999), and Moorthy and Das (1999).

**Net return:** Net return is an important indicator to select the profitable crop combination. Economic analysis of the vegetable-rice production showed that maximum net return over total cost of production was found (1,87,394.5 BDT ha$^{-1}$) in the treatment combination yard long bean + rice (Table 03). The lowest net return (86,752.2 BDT ha$^{-1}$) was obtained from sole rice (Table 03). The higher yield and economic returns in the intercrops were also reported by Mandal et al. (1990).

**Benefit cost ratio (BCR):**

Benefit Cost Ratios (BCR) positively progress while vegetable cultivation was included on the levee of rice. Sole rice gave BCR values of 1.23:1 and vegetable cropping earned much higher BCR values (Table 03). The highest BCR values of 2.01:1 were obtained from yard long bean + rice (Table 03). Other intercropping combinations yielded more than BCR 1.23:1 of sole rice (Table 03). It was astonishing to note that all combinations of vegetable cropping on the ails of rice crop exceeded the sole rice cropping in terms of BCR values (Table 03). Although the highest vegetable production was found in white gourd + rice crop combination but the highest rice equivalent yield, gross return, net return and benefit cost ratio were found in the treatment combination yard long bean + and it was found comparatively more remunerative rice (Table 01-03). Though the vegetable production of this combination was not the highest one in this experiment but it was the best yard long bean production cultivated anywhere. Vegetable production on the levee of rice crop showed better performance than the sole rice in terms of rice equivalent yield, gross return, net return and BCR values (Table 1-3). The probable cause might be that the growth and development of white gourd was not so good in this.
season. From both yield and economical point of view yard long bean was proved as the most suitable vegetable crop for cultivation with rice crop.

Table 03. Total cost of production and return of vegetable-rice cultivation system (data are means ±SD of n=5 experiments)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total cost of production (BDT/ha)</th>
<th>Due to product (a) (BDT/ha)</th>
<th>Due to bi-product (b) (BDT/ha)</th>
<th>Gross return (a+b) (BDT/ha)</th>
<th>Net return (BDT/ha)</th>
<th>Benefit cost ratio (BCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₀</td>
<td>70647.8</td>
<td>138000</td>
<td>19400</td>
<td>157400</td>
<td>86752.2a</td>
<td>1.23a</td>
</tr>
<tr>
<td>T₁</td>
<td>93255.5</td>
<td>263000</td>
<td>17650</td>
<td>280650</td>
<td>187394.5e</td>
<td>2.01e</td>
</tr>
<tr>
<td>T₂</td>
<td>93255.5</td>
<td>261150</td>
<td>16550</td>
<td>277700</td>
<td>184444.5d</td>
<td>1.98d</td>
</tr>
<tr>
<td>T₃</td>
<td>93255.5</td>
<td>231300</td>
<td>16800</td>
<td>248100</td>
<td>154844.5b</td>
<td>1.668b</td>
</tr>
<tr>
<td>T₄</td>
<td>93255.5</td>
<td>245500</td>
<td>16300</td>
<td>261800</td>
<td>168544.5c</td>
<td>1.81c</td>
</tr>
</tbody>
</table>

level of significance *** **

Treatment means having similar letter (s) do not differ significantly. ** Indicates significant at 1% level of significance; Yard long bean, Snake gourd and Yard long bean@26 BDT/ha, Rice grain@20 BDT/ha, Bottle gourd@15 BDT/ha, White gourd@10 BDT/ha and Rice straw@2 BDT/ha

IV. Conclusion

Multiple cropping systems clearly have the potential to increase the long-term sustainability of food production under low inputs in many parts of the world. A better exchange of information among ecologists, environmental scientists, agronomists, crop scientists, soil scientists and ultimately social scientists (e.g. exploring attitudes to uptake, and developing wider cost/benefit analyses) is prerequisite, so that the full potential of intercropping as a sustainable farming system can be realized. Consequently, the results of the present study revealed that, vegetable cultivation along with rice crop is remunerative in both yield and economical point of view. Sole rice cultivation is less profitable than the production of vegetable crops in the levee along with rice.

V. References


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