Agronomic and economic performances of integrated rice-off-season vegetable systems

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Acknowledgement: We would like to thank all the funders who support this research through their contributions to the CGIAR Trust Fund. To learn more about TAFS-WCA and other initiatives in the CGIAR research portfolio, please visit https://www.cgiar.org/research/cgiar-portfolio/.

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1. Introduction

Worldwide, more than 3.5 billion people depend on rice to meet their daily calorie intake (IRRI et *al.* 2010). Rice is the staple food of more than half of the world's population and the most important staple crop in developing countries (Arouna and Aristide, 20219). In sub-Saharan Africa, its consumption is growing faster than that of any other staple food (Seck et *al.*, 2013). Indeed, population growth, changes in their eating habits (Van Oort et al., 2015) and urbanization are explanatory reasons for the increase in their consumption (Dossou-Yovo et al., 2022). By 2028, SSA is expected to have the second-highest annual per capita rice consumption in the world after Asia (Dossou-Yovo et al, 2022). However, domestic production meets only 53% of the demand, and imports come mainly from Asia (Arouna et al., 2021; Asaia et *al*, 2021). Lower rice production compared to the demand in SSA is partly attributed to lower rice yield, which can be related to suboptimal crop management practices (Saito et al., 2018, Dossou-Yovo et al., 2022). Alternative cropping systems, such as improved fallow systems and crop rotation with legumes could overcome soil fertility and rice productivity.

Crop rotation with legumes is one of the best alternatives for plant nutrient management, which is safe for the environment and can effectively reduce the reliance on external inputs (Pokhrel, 2013). Smallholders do not have external inputs or are limited due to high production risk, poverty, and limited access to mineral fertilizers (Croppenstedt et al., 2003; LiverpoolTasie et al., 2017). Low soil fertility is considered to be a major factor in the low productivity of rice in SSA. Therefore, intensifying rice rotation diversification methods with off-season legumes can enable farmers to increase their incomes, improve their food intake, and reduce production risks (Sharma et al., 2005). Thus, legumes can incorporate 15 to 20 t/ha of green manure, i.e. 6% nitric acid and 52.1% organic mineral complex (Pokhrel, 2013). However, there is a limited number of publications on the effects of integrated crop management practices on the performance of rice-based systems. The objective of this study was to evaluate the effects of-season vegetables and legumes on the agronomic and economic performances of rice-based systems.

2. Material and methods

2.1.Study sites

The field experiment was conducted in 2020 – 2022 on the rainfed lowland plot of the Africa Rice Center (AfricaRice) in M'bé (7°53'58′ N, 5°3'3'33′ W), located in central Côte d'Ivoire. The climate is tropical with two dry seasons from November to March and from July to August and two rainy seasons from April to June and from September to October.

2.2.Data collection and analysis

Data were collected on phenology, input use, heights and number of tillers of rice plants, grain of vegetables and legumes, and production costs. Rice yield was determined from 2 zones of 4m2 in the center of each plot and adjusted to 14% grain moisture content. Weight of rice straws after threshing. The tests of normality and homogeneity were conducted and when there was a significant difference, the means were separated using the Least Significant Difference test.

The yield of off-season vegetables was collected from an area of 1 m^2 weighed per elementary plot and then calculated by the formula. The rice equivalent yield (REY) of each vegetable was calculated by converting its grain yield with a price factor according to the following formula:

$$REY(kg.ha^{-1}) = \frac{Cumul\ grain\ yield\ of veg\ (kg.ha^{-1}) \times Price\ of\ veg\ (USDha^{-1})}{Price\ of\ rice\ (USDha^{-1})}$$

Economic indicators were calculated on all fixed and variable costs (tillage, seeds, fertilizers, pesticides, irrigation, harvesting, and post-harvest). The cost of labour used for soil preparation, transplanting, irrigation, fertilization, pesticide application, and harvesting was based on ha^{-1} person-days, and the grain prices of different crops according to the periods were calculated using the formulas (Yabi et al., 2012; Kumar, 2020):

The net benefit of the system was calculated as the difference between the gross yield and the total cost of the crop.

$$Net\ Return\ (USD.ha^{-1}) = Cost\ total\ (USD.ha^{-1}) - \ Gross\ return\ (USD.ha^{-1})$$

$$Benefit\ cost\ ratio = \frac{Net\ Return\ \ (USD.ha^{-1})}{Total\ cost\ (USD.ha^{-1})}$$

3. Results

3.1.Agronomic performance

The highest system rice equivalent yield was recorded in the integrated tomato-rice rotation crop, followed by cucumber rice rotation (Table 1). The lowest system rice equivalent yield was observed in okra–rice rotation and green-bean rice rotation.

Table 1. Rice yield, vegetable yield, rice equivalent yield, and system rice equivalent rice of the cropping systems

Cropping system	Cumulative rice yield (kg/ha)	Vegetable yield (Kg/ha)	REY (Kg/ha)	SREY (Kg/ha)
Cucumber – rice	10537.1 ± 2768.3 a	178806.3 ± 94448.2 b	447015.8 ± 236120.7 bc	457552.9 ± 234104.8 bc
Green bean – rice	10191.9 ± 2299.6 a	19931 ± 7723.8 a	69759.7 ± 27033.5 a	79951.7 ± 26620.91 a
Okra – rice	10704.1 ± 3276.3 a	74345.7 ± 27591.72 a	188468.2 ± 69046.14 ab	199172.3 ± 68323.8 ab
Tomato – rice	10331.3 ± 2509.1 a	182106.1 ± 282431.6 b	637371.2 ± 988510.54 c	647702.6 ± 989209.6 c
p-Value	0.8899	< 0.001	< 0.001	< 0.001
LSD	7663.412	418721.9	1426184	1426399

3.2.Economic performance

The highest net return and benefit-cost ratio were achieved in the tomato–rice rotation system followed by the cucumber–rice rotation system, and these were significantly higher than the net return and benefit-cost ratio of the okra–rice and green bean rice rotation systems (Table 2).

Table 2. Gross return, the net return, and benefit-cost ratio of off-season vegetable crops.

Cropping system	Gross return system(USD/ha)	Net return (USD/ha)	Benefit-cost ratio
Cucumber – rice	88409.13 ± 45191.12 ab	82949.75 ± 45103 ab	15.182287 ± 7.958743 ab
Green bean – rice	28051.65 ± 10749.55 a	22828.75 ± 10110.33 a	4.250947 ± 1.484557 a
Okra – rice	56063.73 ± 20760.99 a	50993.56 ± 20036.10 a	9.733494 ± 2.930014 a
Tomato – rice	284342.70 483275.81 ab	278947.87 ± 483113.39 b	49.829717 ± 83.080256 b
Pr	0.0174 *	0.017 *	0.0134 *
p-value	0.00000305	0.000002065	0.00000008656

4. References

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