

Analysis of rice production and the impacts of the usage of certified seeds on yield and income in Côte d'Ivoire

Impacts of
certified seed
on yield and
income

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Abstract

Purpose – After a long observation of the high rate of rice importation and low productivity in Côte d'Ivoire, the certified rice seed was introduced and encouraged to be used by the local farmers. This study evaluates the profitability of rice production and the impact of certified seed usage on the yield and income of farmers in Côte d'Ivoire.

Design/methodology/approach – Data were collected from 265 rice farmers. Descriptive statistics were used to identify the challenges faced in using certified seeds. Profitability analysis was used to examine the profitability of rice production. To eliminate bias due to the counterfactuals, the endogenous switching regression was employed to investigate the impact of the certified seeds on income and yield.

Findings – The difficulties faced by the rice farmers in the procurement of certified seeds were the unavailability of seeds, the high cost of seeds and poor credit access. Furthermore, rice farmers using certified seeds get a higher net income (USD 263.74/ha) than those using farmers' seeds (USD 212.31/ha). The average treatment on the treated was 1.61 for the yield and 574.75 for the income. The average treatment on the untreated was 1.20 for the yield and 422.59 for the income. These indicate a higher yield and income among adopters of certified rice seed.

Research limitations/implications – Certified rice seed usage is profitable and enhances the output and income of rice farmers. The study advocates the creation of a stronger relationship between the farmers and the extension agents to encourage the use of certified seeds and increase the profit of the farmers.

Originality/value – There is scant information on the profitability of certified rice seed usage and how it affect yield and income. Therefore, this study serves as empirical evidence for policymakers to develop strategies that are required to enhance certified seed usage, boost rice productivity and achieve food security.

Keywords Adoption, Certified seed, Income, Impact, Rice farmers, Profitability

Paper type Research paper

1. Introduction

In various African countries, food security is yet to be achieved, whereas food is seen as the first and most fundamental human right (FAO *et al.*, 2021). In providing a solution to this, agriculture was seen by many researchers as the sector to be developed. Achieving food security is directly linked with agricultural activities (Weerabahu *et al.*, 2022). Today, an increase in agricultural productivity together with putting an end to hunger and malnutrition form the second goal of the Sustainable Development Goals (Abraham and Pingali, 2020). The basis of agricultural improvement is to improve the quality of seeds (Louwaars and De Boef, 2012). Seeds stand as the most important and compulsory input in any sector of crop-related production because, until the farmer plants quality seeds, other inputs such as fertilizer,



pesticides and irrigation water can participate in increasing productivity and production (Etwire *et al.*, 2013). Thus, seeds are the backbone of the agricultural (crop) production system.

The only expansion of cultivated land, without the adoption of innovation, cannot lead to an increase in agricultural productivity. Improvements in technology, such as the production of certified seeds, are the most important in obtaining an increase in productivity as well as strongly beating down the rate of poverty in rural areas (Diagne *et al.*, 2012). Despite the efforts put in place by researchers and agricultural scientists to make the availability of improved and certified varieties of seed prominent, it is still observed that farmers in developing countries still make intensive use of their old grains in the production process (Mwangi and Kariuki, 2015). More than 80% of African smallholder farmers do get their seeds from informal channels; this includes old seeds saved by farmers, farmer-to-farmer seed exchanges and local grain markets (Louwaard and De Boef, 2012).

In many developing countries, agriculture is concentrated in rural areas and mostly done on a small scale by smallholders, characterized by low yields (Chiemela *et al.*, 2021; Larsen and Lilleør, 2014; Mukaila and Arene, 2022). Weak yield from farms results from the high usage of grains from several generations of auto-production (Seye *et al.*, 2016). Improved seed varieties, as opposed to the grains used by farmers, help to increase yield by about 35% (Bogdanović *et al.*, 2015). The adoption of a certified variety of seeds among rural farmers is now questionable. Farmers decide to adopt the planting of certified seeds only when they realize that the profit expected surpasses that of what they gain when using their old seeds (grains) (Marenja and Barrett, 2007). Knowing that seeds are necessary and unavoidable in agricultural production, the high cost of certified seeds constitutes a great constraint in the production process (MAEP Benin, 2019).

In many developing countries, cereals, especially rice, are of vital importance and help to ensure food security (Kumar *et al.*, 2021; Le, 2021; Thanh and Duong, 2021). Rice is considered a staple food, and it is the most consumed food worldwide. Also, looking at its consumption by households in West Africa, its farming is seen to be strongly beneficial in achieving food security in sub-Saharan Africa (SSA) and the black continent at large (AfricaRice, 2012). This intends to stipulate that more efforts should be made to boost the production of the crop, especially in SSA with a high concentration of food insecurity.

In Côte d'Ivoire, rice farming is favorable and is practiced in all regions. However, the country is yet to cover its population's demand for rice despite the presence of both public and private agricultural institutions in the country producing improved varieties of rice seeds and inputs to boost the productivity of rice (Demont *et al.*, 2013). The rice chain constitutes a real source of income for the various actors involved in its business. Côte d'Ivoire remains one of the sub-Saharan African countries with enough resources to develop its rice farming sector. Growing rice in Côte d'Ivoire is linked with several opportunities, such as the availability of high potential land suitable for the production of rice with sufficient precipitation; the availability of many improved varieties of rice seed followed by good organoleptic qualities; a well-developed irrigation system plan; an applied law of land tenure; and high demand for rice at both national and sub-regional levels (ONDR, 2012). However, despite the advancement in technology, such as the availability of certified rice seeds, the nation is second to Nigeria on the list of leading rice importing nations in Africa.

The government of the country has developed several policies in the past to overcome this problem. Among the strategies put in place were "Société de Développement de Riz" (SODERIZ), "Société d'Assistance Technique et de la Modernization de l'Agriculture en Côte d'Ivoire" (SATMACI), "Office National du Développement de la Riziculture" (ONDR) and "Programme national de Riz" (PNR). In 2019, a special ministry for the production and promotion of rice was also established to boost the country's productivity and classify the country among the nations known as an exporter of rice (Afrique-sur-7, 2019). Despite all

these efforts by the government and various research conducted by many other scientists to boost the productivity of rice in Côte d'Ivoire, the use of certified seed, which is identified to be the basic input for agricultural improvement, is still uncommon among rice farmers. Therefore, the need to enhance the use of certified seeds among rice farmers motivates this study.

There exists scanty information on the profitability of certified rice seeds, and how it affects farmers' income and their yield as most previous studies did not emphasize these, especially in Côte d'Ivoire (Addison *et al.*, 2016; Adenuga *et al.*, 2016; Diagne *et al.*, 2012; Seye *et al.*, 2016; Thanh and Duong, 2021). This creates a gap in the literature, which warrants the present study. This study, therefore, analyses the rice production and the impact of the usage of certified rice seeds on income and yield in Côte d'Ivoire to make suggestions on how to improve rice production and increase the use of certified seeds by farmers in Côte d'Ivoire. The specific objectives tend to determine the various constraints involved in the procurement and non-usage of certified seeds; determine the costs and returns of production among the different rice farmers; and determine the impact of the usage of certified rice seeds on the income and yield of the farmers. This would provide sound and right decision-making by the farmers and government. It would serve as empirical evidence for policymakers to develop strategies that are required to boost rice productivity and achieve food security.

2. Literature review

Technology is of capital importance in agricultural production. Modern agricultural technology development aims at reaching two leading objectives: attaining the highest possible yield and deriving the greatest possible economic profit (Rehman *et al.*, 2016). Asfaw *et al.* (2012) opined that, while planning toward meeting the demand for food and the reduction of poverty, it is important to focus on agricultural research and the improvement of technology because they are crucial to achieving the earlier stated goals. Therefore, agricultural technology development is a profitable strategy as it leads to achieving food self-sufficiency and alleviates poverty among smallholder farmers in sub-Saharan Africa.

Rogers (2003) defined technology adoption as the decision to fully apply innovation as the best course of action. Adoption of agricultural technology such as the use of improved seeds positively impacts rural development and economic growth (Sayekti *et al.*, 2020). It increases the income and productivity of the adopters, widens the accessibility of food, and creates more employment and growth linkage effects. Agricultural technology has been identified as the factor that can take the black continent out of poverty. However, its adoption in developing countries is low and slow. In developing countries, the success of the adoption of technology in agriculture relies on two important drivers, the availability and affordability of the technologies and then the sustainability of the profit from the adoption of the technology (Foster and Rosenzweig, 2010).

A large proportion of the literature highlights the determinants of the adoption of agricultural technology. Research has shown that crop insurance and farm size are key determinants of technology adoption (Kumar *et al.*, 2021). Social indices such as age, farm income, education and gender are also major determinants of technology adoption (Foguesatto and Machado, 2022; Kumar *et al.*, 2021; Prasada, 2022). Also, training by extension agents has a positive influence on technology adoption (Le, 2021). Extension agents are categorized as being the bridge between technology innovators (researchers) and technology adopters (farmers). Most often, farmers are informed about new technology, the way it is practiced, and its benefits by extension agents (Mwangi and Kariuki, 2015). Belonging to social groups is very beneficial for farmers in terms of technology adoption (Kirimi *et al.*, 2021). Farmers within such groups easily learn from each other. Thanh and Duong (2021) identified non-farm self-employment, assets, land, labor and ethnicity as the

factors influencing the adoption of the modern variety of rice. Farmers also considered agronomic conformity, postharvest quality, yields of a new rice variety, and the cost associated with making adoption decisions (Atlin *et al.*, 2017; Prasada, 2022). Mensah *et al.* (2021) investigated the impact of using maize seed technology on profitability but did not examine its direct impact on yield and farmers' income.

Most of these previous studies emphasized the drivers of the adoption of technology. Little has been done on costs and returns related to certified rice seed usage and the impact of its usage on farmers' income and yield, especially in Côte d'Ivoire. Meanwhile, one of the most important things farmers do consider before engaging in the usage of new technology is comparing the benefit that the technology will yield with the cost involved in using the technology (Mensah *et al.*, 2021). This is justified by the fact that the farmer is most often motivated by the higher outcome derived from the technology, and when they realize that the net benefit is lower than the prevailing one, they abandon the technology. Thus, the return on investment from adopting a technology enhances farmers' decisions to adopt a technology (Foster and Rosenzweig, 2010; Mensah *et al.*, 2021). The higher the net benefit from technology adoption, the more willing the farmer is to adopt that technology. The present study, therefore, fills this gap by focusing on cost and returns and the impact of certified rice seeds on yield and farmers' income. This would serve as empirical evidence for researchers and add to the existing literature.

3. Methodology

3.1 Description of the study area

This study was conducted in the western and southern regions of Côte d'Ivoire. Côte d'Ivoire is a country located in SSA. It is situated at $8^{\circ}00'N$ and $5^{\circ}00'W$ and covers a total landmass of 322,462 Km². The country relies on agriculture, and the farming of cereal crops is important to the nation's economy. Rice is grown in all regions of the country. In terms of yield, the western part of the country leads the country. However, other parts of the country produce significantly as well. The average production of rice in Côte d'Ivoire from 2013 to 2017 was estimated at 1,871,782 million tons on a land area of 639,579 ha (Fall, 2018). In Côte d'Ivoire, the rain-fed cultivation of rice is the most prominent and dominant, as 73% of the rice produced in the country is under this system of cultivation.

3.2 Source of data, population size and sampling technique

This study involved the use of primary data. The application CS Pro was used to collect primary data on tablets. The data collected for this study include the socio-economic details of the respondents, the different activities involved in the production process; the type of seed used for production; the inputs used and their prices; the cost of labor and the prevailing price of local rice in the market. The target population of interest in this study is made up of rice farmers in Côte d'Ivoire. A three-stage sampling technique was adopted for the selection of the respondents. The first stage was a purposive selection among the hubs identified by AfricaRice and the "Centre National de Recherche Agronomique" (CNRA) in the country. The hubs are localities where rice production is well developed in the country. Hence, these localities were chosen by AfricaRice and the CNRA as experimental fields, and in the long run, the outcomes obtained from these localities will be used and applied to boost the production of rice everywhere in the country. These localities were selected due to the abundant rice production activities and the availability of natural resources favorable for the production of rice. The second stage was the random selection of four localities (Man, Guiglo, Tiassale and Gagnoa) among the identified hubs. The third stage consisted of a random selection of 70 respondents from each of the selected localities. This gives a total sample size of 280 respondents. Of the total, 265 were used for data analysis after sorting and cleaning the data.

3.3 Analytical techniques

3.3.1 Descriptive statistics. To figure out the socio-economic characteristics of rice farmers, descriptive statistics such as the measure of central tendency (mean, frequency and chart) were used. It was also used to identify the constraints encountered in the use of certified rice seeds. A five-point Likert scale was employed by the respondents to rank the severity of the constraints based on their perception. The constraints were considered severe if they had a Likert mean score of up to 3 and considered otherwise if the score is lower than 3.

3.3.2 Profitability analysis. Gross margin was employed to examine the costs and returns of production of rice among the different types of rice farmers. It is a method of estimating the gross profit of an agricultural enterprise after settling the variable costs incurred in the business (Adams *et al.*, 2021; Mukaila, 2022). It is derived that the greater the profit, the better the level of management. The advantage derived from the use of gross margin is that it allows a facile selection of enterprises and an easy establishment of the net farm income (profit). It is also useful in subsistence enterprises with little or no fixed costs. It is specified as:

$$GM = TR - TVC$$

3.3.3 Net profit. This study further estimates the net profit or income to give more insight into the profitability of the ventures. Because the gross margin analysis did not consider the fixed costs in rice production and the farmers incurred some estimable fixed costs, there is a need to ascertain the net profit of the rice production enterprise. The net profit is specified as:

$$\Pi = TR - TC$$

3.3.4 Capital benefit ratio. The capital benefit ratio gives the ratio of net profit to the total cost. It is a percentage of an enterprise's profit. It is specified as:

$$\text{Capital - Benefit Ratio} = \frac{\Pi}{TC}$$

where

GM = Gross Margin

TR = Total Revenue

TVC = Total Variable Cost

Π = Profit

TC = Total Cost

$TC = TFC + TVC$

TFC = Total Fixed Cost

GM = Gross Revenue

3.3.5 Endogenous switching regression (ESR). Propensity score matching has for a long time been a valuable tool used in the study of impact. However, in the randomization process, it is mostly seen that participants, instead of being assigned randomly to the treatment rather choose voluntarily whether to adopt a technology or not after evaluating the profits arising from the unobserved factors, that is called the endogenous selection bias (Wei-Ling, 2005). Therefore, to avoid misstating the treatment effect, it is important to opt for the control of this bias.

The use of endogenous switching regression will facilitate the evaluation of the impact of the use of certified seeds on the yield and income of the farmers. Endogenous switching

regression takes into consideration the effect of bias, the problem of endogenous bias and the generation of results under different counterfactual states of adoption decisions (Malikov and Kumbhakar, 2014). The farmers' decisions to use certified seeds for production can be modeled using a random utility framework.

$$\text{Considering } M_i = U_{i1} - U_{i0}$$

where U_{i1} is the utility gotten from the farmers using certified rice seed, and U_{i0} is the utility gotten from the farmers using farmer's seed (non-certified seed).

When $M_i > 0$, then the farmer is willing to use certified seeds. Also, it is remarked that the two utilities are unobservable but can be modeled as a form of observable function element in the latent variable model (Probit model).

The model is expressed as follows:

$$M_i^* = X_i\beta + \mu_i \dots\dots\dots (\text{selection equation})$$

$$\text{With } M_i = \begin{cases} 1 & \text{if } M_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

where

M_i = Observable variable for the willingness to use certified seed (binary variable).

M_i^* = Unobserved variable (latent variable) for the willingness to use certified seed.

β = Vector of the observed characteristics determining the usage of certified seed.

X_i = Independent variables influencing producer's decision to use certified seed.

μ_i = Error term.

For the endogenous switching regression to be identified, there is a need to include the selection instruments affecting the adoption decision but not the outcome variable (Shiferaw *et al.*, 2014). Hence, to implement this, a simple falsification test was conducted to derive the chi-square and the significant level of the selection instrument. In a linear regression model, we evaluate the impact of the certified rice seeds on the income and productivity of the farmers.

$$Y_i = X_i\theta + M_i\beta + \varepsilon_i \dots\dots\dots (\text{outcome equation})$$

This equation was used twice. First to evaluate the impact of the use of certified seed on the yield of the farmers and, secondly, to determine the impact of the use of certified seed on the income of the farmers.

Y_i = the outcome variable (yield and income of the rice farmers).

M_i = the use of certified seeds.

θ = Vector of parameters associated with X_i to be estimated.

β = Vector of the observed characteristics determining the use of certified seed.

Conditional on selection, the outcomes are well represented by the switching regimes as given in the two equations below.

$$Y_{1i} = X_{1i}\theta_{1i} + \varepsilon_{1i} \quad \text{if } M_i = 1 \dots\dots\dots (\text{users})$$

$$Y_{0i} = X_{0i}\theta_{0i} + \varepsilon_{0i} \quad \text{if } M_i = 0 \dots\dots\dots (\text{Non-users})$$

According to Di Falco *et al.* (2011), the error terms in the selection equation ($M_i = X_i\beta + \mu_i$) are correlated with those in the outcome equation ($Y_i = X_i\theta + M_i\beta + \varepsilon_i$) so we assume they follow a tri-variate normal distribution with zero (0) mean vector and a covariance matrix defined as follows.

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$$\Omega = cov(\mu_i, \varepsilon_{1i}, \varepsilon_{0i}) = \begin{pmatrix} \delta_u^2 & \delta_{1u} & \delta_{0u} \\ \delta_{1u} & \delta_1^2 & . \\ \delta_{0u} & . & \delta_0^2 \end{pmatrix}$$

Here, δ_0^2 is the variance of the error term in the selection equation, δ_1^2 and δ_u^2 are the variances of the error terms in the outcome function. δ_{1u} and δ_{0u} are the respective covariances of μ_i , ε_{1i} and ε_{0i} . As earlier stated, the condition applied to the error terms is to follow a trivariate normal distribution due to the existence of correlation. Due to this correlation, the expected value of ε_{1i} and ε_{0i} , conditional on the sample selection is non-zero (Asfaw *et al.*, 2012). Hence,

$$E = \varepsilon_{1i}|M_i = 1 = \delta_{1u} \frac{\phi(Z_i\alpha)}{\gamma(Z_i\alpha)} = \delta_{1u}\lambda_{1i} \text{ with } \lambda_{1i} = \frac{\phi(Z_i\alpha)}{\gamma(Z_i\alpha)}$$

$$E = \varepsilon_{0i}|M_i = 0 = \delta_{0u} \frac{\phi(Z_i\alpha)}{1 - \gamma(Z_i\alpha)} = \delta_{0u}\lambda_{0i} \text{ with } \lambda_{0i} = \frac{\phi(Z_i\alpha)}{1 - \gamma(Z_i\alpha)}$$

with $\phi(Z_i\alpha)$: standard normal probability function and

$\gamma(Z_i\alpha)$: standard normal cumulative function

From the above equation, the average treatment effect of the treated (ATT) and that of the untreated (ATU) can be derived by a comparison of the expected value among the users and non-users of certified rice seed. This can be computed by following the various equations below:

Farmers that used certified rice seed previously and still used it:

$$EY_{i1}|M_i = 1; X = X_{1i}\theta_{1i} + \varepsilon_{1i}\lambda_{1i}$$

Farmers that do not use certified seeds before and still did not use it:

$$EY_{i0}|M_i = 0; X = X_{0i}\theta_{0i} + \varepsilon_{0i}\lambda_{0i}$$

Farmers that used certified rice seed previously and decided not to use it:

$$EY_{i0}|M_i = 1; X = X_{1i}\theta_{0i} + \varepsilon_{0i}\lambda_{1i}$$

Farmers that do not use certified seeds previously and decided to use it

$$EY_{i1}|M_i = 0; X = X_{0i}\theta_{1i} + \varepsilon_{1i}\lambda_{0i}$$

By computing ATT, we now have the impact of the certified rice seed on each of the outcomes (yield and income) of the producer.

$$ATT = (E[(Y_{i1}|M_i = 1); X] = X_{1i}\theta_{1i} + \varepsilon_{1i}\lambda_{1i}) - (E[(Y_{i0}|M_i = 1); X] = X_{1i}\theta_{0i} + \varepsilon_{0i}\lambda_{1i})$$

In the same line, ATU can be calculated by computing

$$ATU = (E[(Y_{i0}|M_i = 0); X] = X_{0i}\theta_{0i} + \varepsilon_{0i}\lambda_{0i}) - (E[(Y_{i1}|M_i = 0); X] = X_{0i}\theta_{1i} + \varepsilon_{1i}\lambda_{0i})$$

The two variables chosen as selection instruments to obtain a bias-free result in this analysis, the endogenous switching regression, were the distance to the extension agents and the years of farming experience of the respondents.

4. Results and discussion

4.1 Socio-economics characteristics of the respondents

Table 1 gives a summary of the respondents’ demographic, household and institutional characteristics. It shows that among the farmers interviewed, 38.49% of them do make use of

Characteristics	Categories	Producers of rice using Farmers’ seeds	
		Certified seeds (102)	(163)
Age	Mean age	50.42	45.36
	Mean difference		5.07***
	17–35	14 (13.73)	39 (23.93)
	36–65	76 (74.51)	108 (66.26)
	≥66	12 (11.76)	16 (9.82)
Sex	Female	16 (15.69)	9 (5.52)
	Male	86 (84.31)	154 (94.48)
Educational status	None	29 (28.43)	72 (44.17)
	Primary	33 (32.35)	51 (31.29)
	Junior secondary school	20 (19.61)	22 (13.50)
	Senior secondary school	17 (16.67)	17 (10.43)
	University (tertiary)	3 (2.94)	1 (0.61)
Marital status	Married	87 (85.29)	137 (84.05)
	Single	5 (4.90)	18 (11.04)
	Divorced	1 (0.98)	4 (2.45)
	Widow	9 (8.82)	4 (2.45)
Household size	Mean	8.196	6.890
	Mean difference		1.307**
	1–5	28 (27.45)	66 (40.49)
	6–10	53 (51.96)	71 (43.56)
	11–15	15 (14.71)	23 (14.11)
Primary occupation	>15	6 (5.88)	3 (1.84)
	Crop farming	101 (99.02)	154 (94.48)
	Other	1 (0.98)	9 (5.52)
Years of experience	Mean	15.34	14.93
	1–5	18 (17.65)	30 (18.40)
	6–10	23 (22.55)	42 (25.77)
	11–15	25 (24.51)	28 (17.18)
	16–20	8 (7.84)	23 (14.11)
	>20	28 (27.45)	40 (24.54)
Member of association	Yes	49 (48.04)	100 (61.35)
	No	53 (51.96)	63 (38.65)
Contact with extension agents	No	16 (15.69)	71 (43.56)
	Yes	86 (84.31)	92 (56.44)
Number of extension agent visit/year	1–5	77 (89.53)	89 (96.74)
	≥6	9 (10.47)	3 (3.26)
Access to credit	No	99 (97.06)	157 (96.32)
	Yes	3 (2.94)	6 (3.68)
The amount borrowed in USD	Mean	420.13	316.67
	Mean difference	103.47	

Table 1. Distribution of respondents by demographic and household characteristics

Note(s): Figures in parenthesis are percentages
****p* < 0.01; ***p* < 0.05

certified seeds for sowing, while 61.51 % used farmer's seeds. The users of certified seeds are older than those using farmer's seeds, which corroborates the findings of [Adenuga et al. \(2016\)](#). There was low female participation in the production of rice. This low involvement of women in the rice farming sector is consistent with the findings of [Addison et al. \(2016\)](#), who reported that rice farming is a labor-intensive activity, and men are more involved in the sector than women. The majority of the rice farmers using certified seeds had an educational background, while about 44% of the users of farmers' seeds had no formal education. Thus, educated farmers embrace the adoption of new technology more than uneducated ones ([Akanbi et al., 2020](#); [Mukaila et al., 2021](#); [Mwangi and Kariuki, 2015](#)). The majority of the respondents in the two categories of farmers are married. Considering the mean age of the entire sample for the study and the area of study (sub-Saharan Africa), this result becomes justifiable in the sense that in this part of the globe, people get married very early. The analysis of the respondents' household size revealed that the users of certified seeds majorly had a larger household size (8) than the non-users (7). The study shows that the majority of the respondents are primarily crop farmers and consider farming as a primary occupation and source of income. This supports previous findings that the majority of sub-Saharan African nations and their populations strongly depend on agriculture as their primary source of income ([Falola et al., 2022a](#); [Mukaila et al., 2022](#)). The rice farmers are well-experienced. The rice farmers using certified seeds had more farming experience than the farmers using farmer's seeds, which could be one of the reasons that influenced their decision to adopt certified rice.

More than half of the respondents belonged to an association ([Table 1](#)). Generally, associations have been proven to positively influence the adoption of innovation and assist their members to achieve favorable and beneficial outcomes. Agricultural associations such as cooperatives impact household savings and assets, the level of input expenditure, household income and the adoption of innovation ([Falola et al., 2022b](#); [Wossen et al., 2015](#)). Although a larger portion of the farmers had contact with extension agents, the rate of contact with extension services is higher among the users of certified seeds than among the users of farmers' seeds. This could greatly influence farmers to adopt innovations such as certified seeds and improve their productivity levels. This is because extension agents inform farmers about innovation and its advantages. Thus, a very important channel through which information can reach farmers is a well-established and functioning system of extension services ([Mwangi and Kariuki, 2015](#)). On average, the number of extension agents' visits to the respondents' farms falls between 1 and 5 per year. A very low proportion of the respondents had access to loans. Those using certified seeds borrowed an average of USD 420.13, while those using farmer's seeds borrowed an average of USD 316.67.

4.2 Difficulties militating against the procurement of certified seeds

[Table 2](#) reveals the difficulties faced by farmers in procuring certified rice seeds. The majority of them agreed that the high cost of certified seeds is the biggest difficulty they face. The next difficulty with this is the unavailability of certified seeds in the production areas. This shows that the unavailability of improved varieties of seeds is still prevailing in the SSA ([Awotide et al., 2013](#)). Low financial power to purchase certified seeds is also seen as a severe constraint

Difficulties	Mean	Rank
High cost of seeds	4.57	1
Unavailability of seeds	4.56	2
Low financial power	3.15	3

Table 2.
Difficulties linked to
the procurement
of seeds

in procuring certified seeds for production. Insufficient resources, especially capital, is a major constraint in food crop production (Akanbi *et al.*, 2022). This suggests that subsidizing certified seeds by the government would enhance the use of certified seeds among rice farmers.

4.3 Constraints related to the non-usage of certified seeds

In Table 3, the constraints linked to the non-usage of certified rice seeds were revealed. The majority of the rice farmers stand by the fact that the lack of access to credit is the major constraint stopping them from using certified seeds. Farmers having access to credit might not directly realize an impact on productivity, but indirectly, this could positively and significantly push the farmer to embrace the idea of technology adoption. Also, farmers that adopted improved planting materials obtained higher credit (up to 36%) than non-adopters. This shows that the adoption of technology has a dual effect; it helps to improve farm productivity and also eases access to credit for farmers. The high cost attached to the procurement of the certified seeds was also viewed by the farmers as the next constraint to their willingness to use certified seeds. This justifies the first constraint mentioned in the sense that, due to the latter, farmers seek credit to purchase certified seeds. The third most important constraint pointed out by farmers is the problem of accessing certified seeds. Most often, places where certified seeds are sold are far away from the areas of production or places of residence of the rice farmers. Without the proper information on the availability of certified seeds, farmers are pushed to use their colleagues' or their seeds (farmer's seeds). Furthermore, the majority of the respondents had no information about the availability of new varieties of rice seeds. Another severe constraint is the problem of finding paid labor to conduct farm operations within the proper time frame. Other constraints are the weak linkage between rice seed actors and the market; lack of information about the availability and existence of certified seeds; uncertainty and doubt (no trust) about the quality of certified seeds; the high risk involved in rice production; and the self-perception that the certified seed will have a weak impact on the productivity of the farm.

4.4 Profitability of rice production

Table 4 reveals that the average yield of the rice farmers using certified seeds (2.43 tonnes/ha) is greater than that of those farmers using farmer's seeds (2.19 tonnes/ha). The resulting difference in the mean yield (0.24 tonnes/ha) is statistically significant at 10%. This stipulates that the use of certified rice seeds in the production of rice leads to a greater yield than the use of farmer's seeds. This supports Awotide *et al.* (2013) that the yield of the users of voucher seeds was higher than the yield of farmers using farmer's seeds. Both categories of farmers sold their paddy rice at the price of USD 0.33 per kg. The total revenue (TR) of the farmers

Table 3.
Constraints related to
the non-usage of
certified seeds

Constrains	Mean rank	Rank
Access to loan/credit	4.92	1
High cost of certified seeds	4.49	2
Problems with accessing or procurement of certified seeds	4.39	3
Finding paid labors to conduct the farming operations within the proper time frame	4.34	4
The weak linkage between the rice seed actors and the market	3.74	5
Lack of information about the availability and existence of certified seeds	3.43	6
Uncertainty and doubt (no trust) on the quality of certified seeds	3.37	7
High risk involved in the production of rice	3.21	8
Self-perception that the certified seeds will have a weak impact on the productivity	3.1	9

Expenditures	Units	Types of seeds used		Difference	Impacts of certified seed on yield and income
		Farmers' seeds	Certified seeds		
Yield (Q)	Kg/ha	2191.00	2434.46	-243.46*	
Mean price of paddy rice (<i>P</i>)	USD/kg	0.33	0.33	-	
Total revenue (A = <i>Q*P</i>)	USD/ha	723.03	803.51	-80.34**	
Seeds	USD/ha	27.30	35.53	-8.23***	
NPK	USD/ha	32.91	31.69	1.22	
Urea	USD/ha	41.41	29.19	12.22**	
Herbicides	USD/ha	31.04	16.64	14.40***	
Insecticides	USD/ha	4.63	7.06	-2.43**	
Other inputs	USD/ha	0.50	0.51	0.01	
Total variable cost (B)	USD/ha	137.79	120.62	17.17*	
Gross margin (C = A-B)	USD/ha	585.24	682.75	-97.51**	
Labor cost (D)	USD/ha	361.94	407.57	-45.63*	
Interest (E)	USD/ha	2.84	0.71	2.13	
Gross Income [F = C-(D + E)]	USD/ha	220.59	274.61	-54.02	
Depreciation	USD/ha	8.28	10.86	-2.58*	
Total cost (G)	USD/ha	510.85	539.76	-28.91	
Profit/Net income (H = A-G)	USD/ha	212.31	263.74	-51.43	
Benefit-cost ratio (H/G)	-	0.42	0.49	-0.07	
Note(s): *** <i>p</i> < 0.01; ** <i>p</i> < 0.05; * <i>p</i> < 0.1					

Table 4.
Cost and return
of rice production

using certified seeds was higher than those using farmers' seeds. The resulting difference in the mean gross income (USD 80.34) was significant.

In the breakdown of the variable costs, as expected, the cost per hectare of purchasing certified seeds was greater than that of farmers' seeds. An evaluation of the cost per hectare of NPK used reveals that there is no significant difference in the mean cost of the users of certified seeds and farmers' seeds. However, there was a significant difference, at 5%, in the mean cost of urea used among the two types of farmers. The urea cost per hectare of the users of certified seeds was lower than the farmers using farmer's seeds. The result of the usage of herbicide among the different types of farmers reveals that there is a significant difference in the average cost per hectare. The average cost per hectare of herbicide used by the farmers using certified seeds was lower than the average amount spent on herbicide by the farmers using farmers' seeds; this is almost double that of the users of certified seeds. However, the opposite is observed in the usage of insecticides. The average cost per hectare of insecticide for the users of certified seeds was higher than that of those using farmers' seeds. Furthermore, the users of certified seeds spent more on labor (USD 407.57) than the users of farmers' seeds (USD 361.94); the difference in the mean cost is statistically significant at 10%. This might be the reason for the farmers using farmers' seeds to spend more on herbicides than the users of certified seeds. The cost per hectare of other inputs such as transportation and security are the same for the two types of farmers. The total variable cost (TVC) for the farmers using certified seeds was higher than for the users of farmers' seeds. The difference in these costs (USD 17.16) is statistically significant at 10%.

The gross margin derived from the above TR and TVC per hectare was higher among users of certified seeds (USD 682.75) than among those using farmers' seeds (USD 585.37). The difference in the gross margin obtained (USD 97.51) was statistically significant at 5%; this stipulates that if only the TVC is considered as an expenditure of production, the users of certified seeds realize a greater and more significant profit (USD 97.51 per hectare more than the users of farmer's seeds).

The gross income or gross profit, the income left after subtracting all the production costs from the total revenue from rice production, determines the profit realized from production.

The gross income of the farmers using certified seeds (USD 274.61/ha) was higher than the farmers using farmers’ seeds (USD 220.59/ha). The certified users made a gross margin of USD 54.02 higher than the non-users, whereas it is essential to consider the other costs involved in the production to obtain the exact profit (net income).

The depreciation of implements and tools used in the production process is greater for the users of certified seeds (USD 10.86/ha) than for the users of farmers’ seeds (USD 8.28/ha). The interest paid on loans received by the users of farmers’ seeds (USD 2.84/ha) was higher than that of the users of certified seeds (USD 0.71); statistically, the difference in the average interest paid (USD 2.13) is significant at 1%. The overall total cost (TC) of production was USD 510.85 for the users of farmers’ seeds and USD 539.76 for those using certified seeds. Farmers using farmers’ seeds realize a net income of USD 212.31/ha; the net income for the users of certified seeds was USD 263.74/ha. The users of certified seed made a profit of USD 51.43 higher than the non-users. The resulting cost–benefit ratio was 0.42 and 0.49 for the farmers using farmers’ seeds and the users of certified seeds, respectively. This means for every USD 100 invested, the farmers using farmers’ seeds raise a profit of USD 42, while the other group of farmers using certified seeds realize a profit of USD 49. These results imply that users of certified seeds made a higher profit than those using farmers’ seeds. Thus, the use of certified seeds is economically viable and yields a higher investment return. Similarly, [Mensah *et al.* \(2021\)](#) reported that farmers who used certified seeds made a higher profit than those that used their seeds.

4.5 Impact of the usage of certified seed on the yield

[Table 5](#) shows the expected yield per hectare obtained under real and counterfactual conditions. The users of certified seeds got an average yield of 2.44 tonnes/ha, as observed in cell a. In cell b, it is seen that the non-users of certified seeds obtained an average yield of 2.18 tonnes/ha. Based on this fundamental difference, certified seed users gain 260 kg (more than 14 tonnes) more per hectare than non-certified seed users. [Diagne *et al.* \(2012\)](#) also reported that improved varieties of seeds have a positive impact on the yield. However, while considering the treatment effect, the average treatment of the treated (ATT) observed was 1.61 tonnes/ha. This means that the users of certified seeds would have made a loss of 1.61 tonnes/ha if they had not adopted certified seeds. It is also observed in the counterfactual that the average treatment of the untreated (ATU) was 1.2 tonnes/ha. This means that if the non-users of certified seeds had adopted certified seeds, they would have made a yield of 3.38

Subsample	Decision stage		Treatment effect
	Adopt	Did not adopt	
Users	(a) 2.44	(c) 0.83	TT = 1.61***
Non-users	(d) 3.38	(b) 2.18	TU = 1.20***
Heterogeneity effect	$BH_1 = -0.94$	$BH_2 = -1.35$	TH = 0.41
Wald $\chi^2(18) = 62.05$			
Prob > $\chi^2 = 0.0000$			
Log likelihood = -440.49			
Sigma (σ_i) = 0.49			
Rho (ρ_j) = -1.47			
LR test of indep. Eqns			
$\chi^2(1) = 6.03$			
Prob > $\chi^2 = 0.0140$			
Note(s): (a) Expected YIELD of the users that adopt certified seeds; (b) Expected YIELD of the non-users that did not adopt certified seeds; (c) Expected YIELD of the users that did not adopt certified seeds; (d) Expected YIELD of the non-users that adopted certified seeds			

Table 5.
Expected average yield per hectare; treatment effects (TEs) and heterogeneity

tonnes/ha (that is 1.2 tonnes/ha more than what they obtained). A student test was administered to each group (treated and control), and the results were significant at 1%. The obtained results imply that the use of certified seeds had a positive impact on yield. However, it should be noted that the positive effect of transient heterogeneity (TH = 0.41) stipulates that the non-users will suffer greater loss if they do not adopt certified seeds.

Impacts of
certified seed
on yield and
income

4.6 Impact of the usage of certified seed on the income of farmers

Table 6 shows the expected income per hectare obtained under real and counterfactual conditions. The users of certified seeds got an average income of USD 260/ha, as observed in cell a. In cell b, it is seen that the non-users of certified seeds obtained an average income of USD 216.35/ha. Relying on this basic difference, we deduced that the users of certified seeds gain up to USD 43.65 on each hectare more than the non-users of certified seeds. The ATT obtained (574.85) was higher than the ATU (422.66). These results were also found to be significant at 1%, while verifying the robustness of the ESR using the student test. It is also observed in the counterfactual that if the non-users of certified seeds had adopted certified seeds, they would have made a large income of about USD 639.01/ha. The obtained results and interpretations lead us to conclude that the use of certified rice seeds had a positive impact on income. This supports Awotide *et al.* (2013), in a study conducted among rural farmers in Nigeria, that improved rice varieties when adopted have a positive impact on household income. However, it should be noted that the obtained effect of transient heterogeneity is positive (TH = 152.19). This simply means that if the non-users do not adopt certified seeds, they will suffer a greater loss in income.

5. Conclusion and policy recommendations

This study investigates the production of rice vis-à-vis challenges and profitability. It also highlights the impact of using certified seeds in the production of rice on the yield and income of farmers. The rice farmers encountered difficulties in the procurement of certified rice seeds; these are the unavailability of seeds, the high cost of seeds, and the low financial power to purchase certified seeds. The reasons for the non-usage of certified seeds were lack of access to loans and the high cost of certified seeds. The study shows that rice farmers using certified seeds for production obtained a greater net profit than those using farmers' seeds.

Subsample	Decision stage		Treatment effect
	Adopt	Did not adopt	
Users	(a) 260.00	(c) -314.85	TT = 574.85***
Non-users	(d) 639.01	(b) 216.35	TU = 422.66***
Heterogeneity effect	$BH_1 = -379.01$	$BH_2 = -531.11$	TH = 152.19
Wald $\chi^2(18) = 38.35$			
Prob > $\chi^2 = 0.0035$			
Log likelihood = -2027.87			
Sigma (σ_i) = 97.9			
Rho (ρ_j) = -1.313			
LR test of indep. Eqns			
$\chi^2(1) = 5.12$			
Prob > $\chi^2 = 0.0237$			

Note(s): (a) Expected income of the users that adopt certified seeds; (b) Expected income of the non-users that did not adopt certified seeds; (c) Expected income of the users that did not adopt certified seeds; (d) Expected income of the non-users that adopted certified seeds

Table 6.
Expected average
income per hectare;
treatment effects (TEs)
and heterogeneity

Furthermore, the users of certified seeds got a higher average yield than non-users of certified seeds. The users of certified seeds also got a higher average income than the non-users of certified seeds. Therefore, the use of certified seeds had a positive impact on yield and income, and the rice farmers using certified seeds are better off than those using farmers' seeds.

Focusing on the findings of this research work, the following recommendations are made:

Access to credit should be made easier for farmers since it has been a limitation in both the purchase and the use of certified seeds; it would enable them to engage more in adopting certified seeds and hence boost their yield and income. This could be achieved through financial institutions and government intervention in the form of loans and grants. A farmer-extension agents' network should be established to create more awareness about the advantages and availability of certified seeds, provide training to the farmers on the use of certified seeds and schedule more frequent visits to the farmers. This would build a tight relationship between farmers and the extension agents. There is also a need to make production inputs, especially the certified rice seeds, available and cheaper (subsidized) for the farmers. Farmers should be motivated to form or belong to an association where they can get benefits such as training and financial assistance as a group from the government and research institutions.

Due to the concentration of this study on two regions of Côte d'Ivoire, future studies should consider a larger sample size that covers more areas. In addition, we suggest using other types of analyses, such as cluster analysis, to better understand the profile of farmers that use and do not use certified seeds.

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