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Effects of Sowing Methods on Paddy Rice Yields and Milled Rice Quality in Rainfed Lowland Rice in Wet Savannah, Togo

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ABSTRACT

Identifying the socio-economic constraints of seeding technologies uptake and analyzing the yields, milled quality and growers' income under various seeding methods are a strategy for sustainable rainfed lowland rice. A survey and an on-farm experiment were carried out at five locations with a random sample of 50 farmers grouped in five of the fourteen partner cooperatives of ESOP-Pagouda. The survey focused on socio-economic data collection. The experiment, replicated at five locations, involved three treatments: broadcast seeding, direct seeding, and transplanting. The paddy rice yields and milled rice quality were analyzed using R software version 4.1.3, and arithmetic means discriminated at the 5% by the Duncan test. The profitability indicators, such as the Gross Margin (GM) and the Benefit/Cost Ratio (BCR), were calculated. The results showed that 14% of farmers adopted rice transplanting method. The transplanting method increased rice yield (3.3 t/ha) compared to direct seeding (2.8 t/ha) and broadcast seeding (2.2 t/ha). The milled long grain rate (56%) was significantly higher than those under both seeding methods. Additionally, the transplanting method improved the gross margin (1,146 $USD/ha) compared to 663 $USD/ha and 431 $USD/ha for direct and broadcast seeding, respectively. The benefit/cost ratio 1.5 for transplanting was almost double from that of both seeding methods. Despite its high demand for labor and agricultural inputs, the transplanting method provided the highest paddy rice yields and milled rice quality to improve farmers' income.

INTRODUCTION

Source of carbohydrates for human nutrition and second most cereals consumed after wheat, rice crop provides for most of the world's population (Dianga *et al.*, 2021; Bassuony & Zsembeli, 2019; Graham-Acquaah *et al.*, 2018). In Sub-Saharan Africa (SSA), where 30% of the population is in extreme poverty and food insecurity, demand for rice increases due to population growth and a shift in consumer preference (Balasubramanian. *et al.*, 2007). Unfortunately, local rice production cannot keep up with or satisfy the rising global demand for rice despite the potential for rice production (Graham-Acquaah *et al.*, 2018). Rice production is still characterized by low paddy yields, high post-harvest losses and low milled yields (MAEH, 2016). The yield increase rate was not sustaining to attain rice self-sufficiency (Arouna *et al.*, 2021). The national production deficit is compensated by rice imports of sometimes dubious quality, resulting in a significant foreign exchange leakage (Arouna *et al.*, 2021; Yovo, 2010).

To achieve improved productivity, the challenge is to find sustainable, accessible technologies (Guibert *et al.*, 2016). According to Abdulai *et al.* (2018), adopting improved agricultural techniques can increase rice production. Unfortunately, several personnel constraints, psychological constraints, and socio-economic constraints, including demanding access to irrigation water, a lack of high-quality seeds, a lack of farmer knowledge and training, and high input (irrigation, fertilizer, labor, seeds) costs, prevent the adoption these new technologies (Shriwas *et al.*, 2019; John & Fielding, 2014). Many factors, such as agronomic practices, affect the yield and quality of milled rice directly or indirectly (Ilieva *et al.*, 2019). So, the innovative technologies should not only increase paddy yields, but also improve the milled rice quality and the farmers' income. Thus, for both farmers and consumers, rice's value can increase with improved grain quality (Prom-u-thai and Rerkasem, 2020).

According to several researchers (Arsil *et al.*, 2022; Balamurugan & Rajasekaran, 2019; Kahimba *et al.*, 2014), the system of rice intensification (SRI) is an agronomic approach for increasing rice productivity by using fewer inputs for more outputs. However, its adoption by the rice growers requires changing the farming practices as sowing method. The farmers should abandon direct and broadcast seeding methods widely practiced for transplanting methods. Thus, lowland rice farmers organized in cooperatives were trained in transplanting through the on-farm demonstration method (Donkoh *et al.*, 2019; Rashid *et al.*, 2019; Udimal *et al.*, 2017).

In addition, the studies showed that the seeding methods influence the rice yield and milled rice quality (Rashid *et al.*, 2019; Sorkpor, 2015; Rana *et al.*, 2014; Bhuyan *et al.*, 2012). However, researchers are divided on the best method for planting rice. Some (Bassuony and Zsembeli, 2019; Troy and Picaud, 2013; Bhuyan *et al.*, 2012; Krupnik *et al.*, 2012; Ehsanullah *et al.*, 2007) believe that the transplanting method is a new approach to increasing grain yield, for improving water and fertilizer use efficiency, for improving significantly the milling characters and the 1,000-grain weight. Others (Chen *et al.*, 2020; Dendup *et al.*, 2018; Kaur & Singh, 2017; Rana *et al.*, 2014) argue that

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the direct seeding and broadcasting methods get many advantages like less labor, low production cost, less water use, less methane emission, high economic profit, low crop maturity duration. Facing this scientific divergence, determining the difference in yield and milled rice quality and farmers' profitability under various sowing methods is the way to sustainable rice growing. The objective is to assess the effects of rice sowing methods on yield and milled rice quality for improving the small farmers' income and consequently enhancing the rate of transplanting method uptake.

MATERIALS AND METHODS

Study Area

The study was carried out from March to December 2021 at five locations in the humid savannah, between 9°44'0" North and 1°19'0" East, with the Republic of Benin in the East (Figure 1). This area has a Sudano-Guinean climate characterized by an alternating dry season from November to April and a rainy season from May to October. The average annual rainfall varies between 900 and 1000 mm, with extreme temperatures between 18 and 40°C. The soils, hydromorphic and ferruginous tropical types, are little evolved from erosion and alluvial input (Faure, 1985). The relief, which is very varied, is made up of alternating plains, valleys, and plateaus dominated by old rugged massifs, with quite contrasting aspects that extend to the borders of Benin and Ghana. The hydrographic network is essentially characterized by the Kara River and its tributaries, a Volta sub-basin. This area has enormous lowlands intended mainly for rainfed rice cultivation, hence the choice for this study.

Plant Material and Fertilizers

The plant material was the IR841 variety because of its production by all the farmers in the study area. This aromatic grain variety, introduced in 1973, is adapted to all regions of Togo, is resistant to lodging and has an average yield of 3-4 t/ha with a potential of 6 t/ha (Adomefa *et al.*, 2007). The mineral fertilizers used are N15P15K15 complex and urea 46%.

Processing and Measurement Equipment

The processing equipment consisted mainly of:

- an electronic winnowing machine to remove all impurities from the paddy rice, such as sand, stones, weed seeds, plant debris, and empty rice husks;
- a hulling machine to remove the husk from the paddy;
- a manual winnowing machine to remove all kinds of impurities from the husked rice; especially empty husks
- a grading machine to separate the whole grains from the broken grains;
- basins for sorting and winnowing;
- a weighing machine to determine the weight of the different products.

Data Collection Materials

Socio-economic data were collected using a questionnaire administered to farmers' members of the partner cooperatives of the enterprise of services and organization of producers (ESOP-Pagouda). Then, a form was established for the monitoring and field data collection from soil preparation to harvest and post-harvest activities.

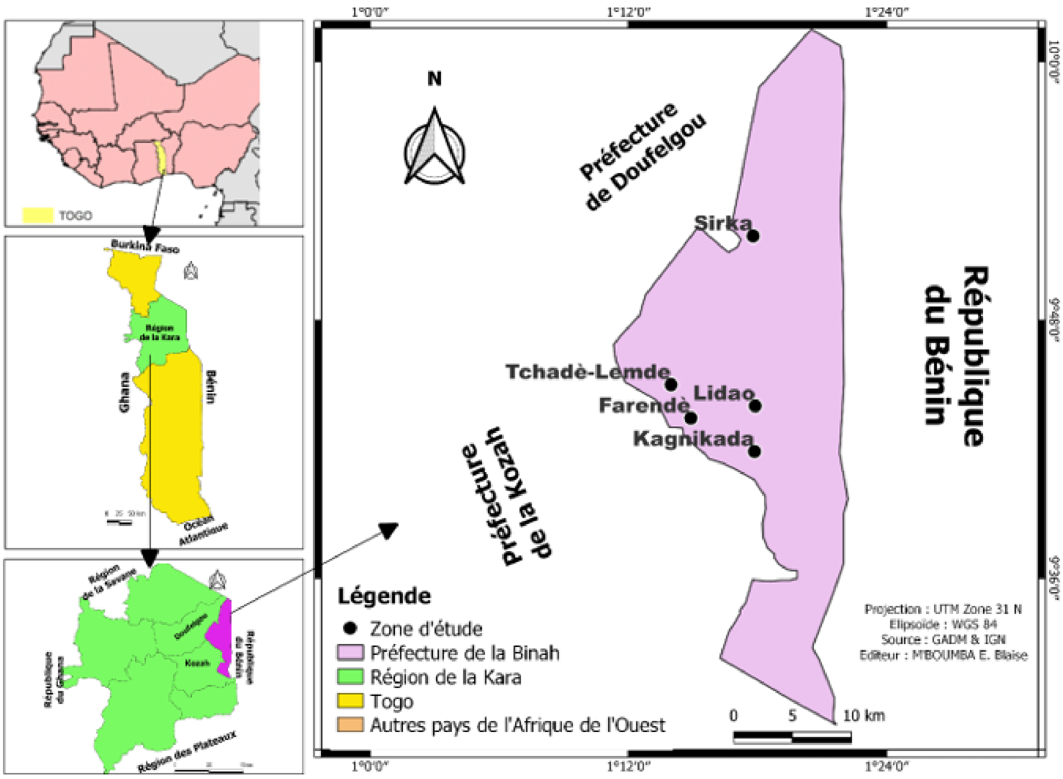

Figure 1: Study Area Map

Sampling and Experimental Design

First, a survey was conducted among 50 farmers out of 147 grouped into 14 partner cooperatives of the enterprise of services and organization of producers (ESOP-Pagouda) to collect socio-economic data. Thus, a sample of 5 cooperatives was randomly selected to conduct the trial, which was set up on-farm with three treatments: broadcast seeding, direct seeding, and transplanting. These locations are: Farendè, Kagnigada, Lidao, Tchadè-Lemdè and Sirka. Each treatment of 0.25 ha was replicated simultaneously at the same time in the five localities covered by this study.

Setting up the crops

The setting up of the crops began with the choice and the land preparation, which included clearing, plots delimitation of 0.25 ha each, and plowing followed by harrowing. The plots' borders were then raised to an average height of 30 cm to ensure water availability throughout the growing season and to avoid fertilizer losses through runoff. The prepared seeds were put in the nursery at a rate of 100 g/m^2. A second part was sown directly in line and by pocket at a rate of 3 to 5 grains by pocket according to a spacing of 15 cm × 20 cm as recommended by Uddin *et al.* (2011), and a third part was sown by the broadcast method. The transplanting was performed after ten days of nursery according to a spacing of 15 cm × 20 cm as recommended by Uddin *et al.* (2011). The seedlings were removed two weeks after direct seeding to maintain three plants/pocket. For mineral fertilization, 200 kg/ha of N15P15K15 was applied before sowing as basal fertilizer, 150 kg/ha of Urea 46% was applied at tillering initiation and panicle initiation in the order of 100 kg/ha, and 50 kg/ha. 120 kg/ha of potassium chloride was applied at the panicle initiation stage. The weeds were manually removed to avoid losses in rice quality and yield.

Harvesting occurred in the morning (6:00 to 10:00 a.m.) before the heat of the day or in the afternoon (3:00 to 6:00 p.m.). Harvesting, threshing, and winnowing were all done manually. Grain yields of paddy rice were calculated using the following formula:

Yield (t/ha)=(outputs (t)/area surface (ha) .....(1)

Pre- and post-harvest operations

In order to ensure that the results observed were related only to the sowing method, the pre- (site selection, soil preparation, sowing, fertilization, maintenance, harvesting) and post-harvest operations (drying, threshing, winnowing, storage, shelling, grading.) happened under the same conditions. Harvesting took place when the entire rachis of the panicles of most (at least 2/3) of the plants on the plot was straw-colored or golden yellow since harvesting too early results in mealy grains and harvesting too late (grain too hard) results in high shattering rates.

The processing steps were as follows:

1. electronic winnowing to remove dust, stones, sand, and other debris from the paddy
2. hulling to separate the paddy from its outer husks
3. sorting and manual winnowing of unhulled grains and weed seeds by women
4. sizing to separate chips from long grains
5. conditioning.

Data Collection

The different yields of paddy and milled rice were determined by weight measurement. Milling yield is defined as the ratio of milled whole rice weight to broken paddy weight, and breakage rate as the ratio of broken grain weight to total milled rice weight (Laignelet *et al.*, 1983).

The various milled rice rates are estimated from the formulas below:

HRR=QMRH/(QPR)*100 (2)

LGR=QLGS/(QMRH)*100 (3)

BR =QBS/QMRH*100 (4)

where: HRR = hulled rice rate; QMRH = quantity of milled rice obtained after hulling; QPR = quantity of paddy rice; LGR = Long grain rate; QLGS = Quantity long grain obtained after sizing; BR = breakage rate

The quality assessment and comparison parameters of milled rice are:

1. cleanliness of paddy rice;
2. hulling rate;
3. bran content;
4. rate of whole grains;
5. rate of broken grains.

Data Analysis

The socio-economic data collected was entered into IBM SPSS Statistics 20 software, from which the various percentages and averages were calculated. The data of paddy and milled rice yields and rice bran were used to compare the different treatments using R software version 4.1.3 by analysis of variance. The different arithmetic means of the different treatments were discriminated and compared by the Duncan test at the 5% threshold when a significant difference was found. Percentage data were transformed using a circular function $y=\arcsin\sqrt{(X/100)}$ in order to homogenize the variances and to ensure normality to the off-axis distributions.

Profitability Analysis

To make the comparative analysis of the profitability of the different sowing methods, the indicators such as the Gross Margin (GM), the Benefit/Cost Ratio (BCR), and the Internal Rate of Return (IRR) were determined from the following formulas:

GM=GP-IC (5)

BCR=GM/IC (6)

where GM = Gross Margin, GP = gross product and I C = input cost

RESULTS

Socioeconomic aspects and sowing methods practiced

by rice farmers

The results showed that men represent 88% of the rice farmers surveyed. Membership in the cooperatives ranged from 7 to 13, with women ranging from 0 to 30% (Figure 2). Only the others are widows. All the females were widows except one woman whose husband was a teacher. Ninety-two percent of the rice farmers were illiterate, 8% had primary education, and most did not know their age. The results revealed that the area sown by women is comparatively higher than that held by men. However, over 85% of the rice farmers had fewer than 2 ha (Figure 3). The small size of the areas sown results from traditional rice cultivation, with farming operations carried out by hand, without mechanization.

Of the total number of rice farmers, about 60% practiced direct seeding, and only 14% had adopted transplanting (Figure 4). In all the study locations, transplanting was poorly adopted as opposed to direct seeding, which is preferred. However, in Sirka, broadcast seeding was more widely observed (Figure 5). In addition, the results indicated that 5% of male farmers adopted transplanting, and 7% of female farmers adopted transplanting.

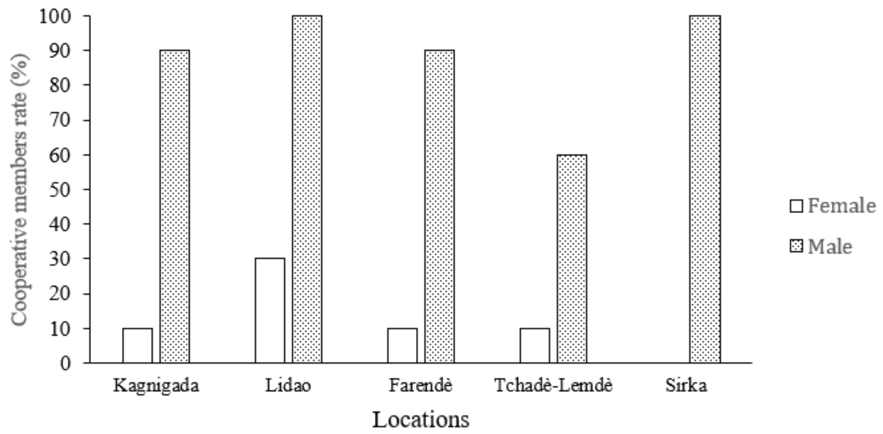

Figure 2: Distribution of cooperative members according to gender

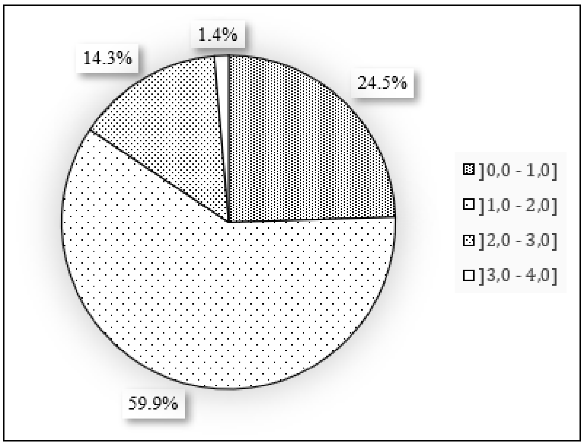

Figure 3: Plots' area of the farmers

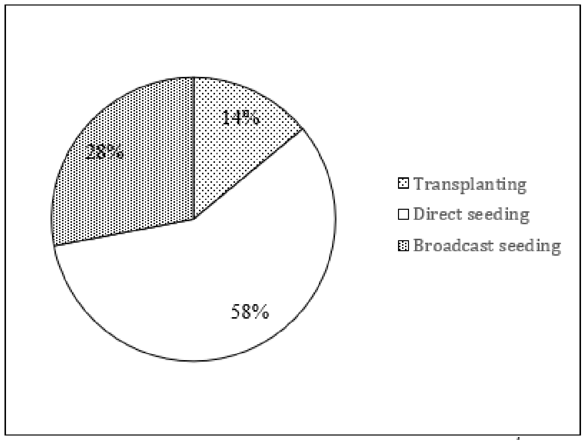

Figure 4: Sowing methods adopted rate by farmers

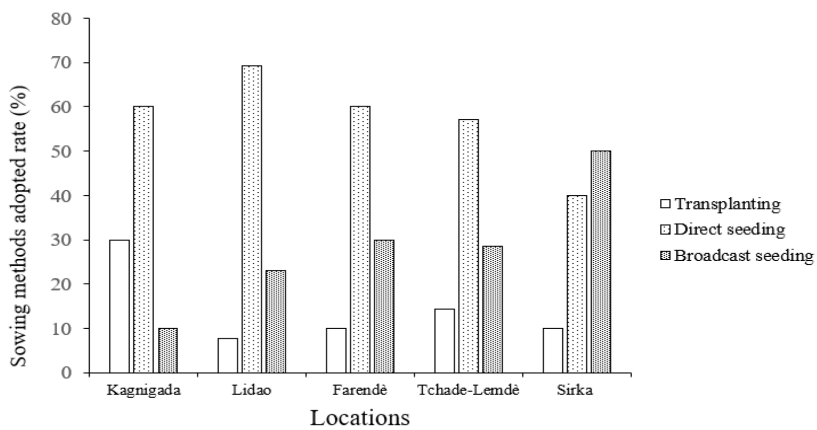

Figure 5: Sowing methods adopted rate by location

The adoption constraints to transplanting expressed by rice farmers were diverse. These included a lack of labor and financial resources, as transplanting requires additional work; habits based on traditional practices; lack of knowledge of the transplanting technique; lack of monitoring and supervision technicians; etc. (Figure 6). The rice growers widely mention constraints related to the lack of financial resources and labor at 92 % and 86 %, respectively. However, the conservation of traditional agricultural practices is little mentioned at 22%.

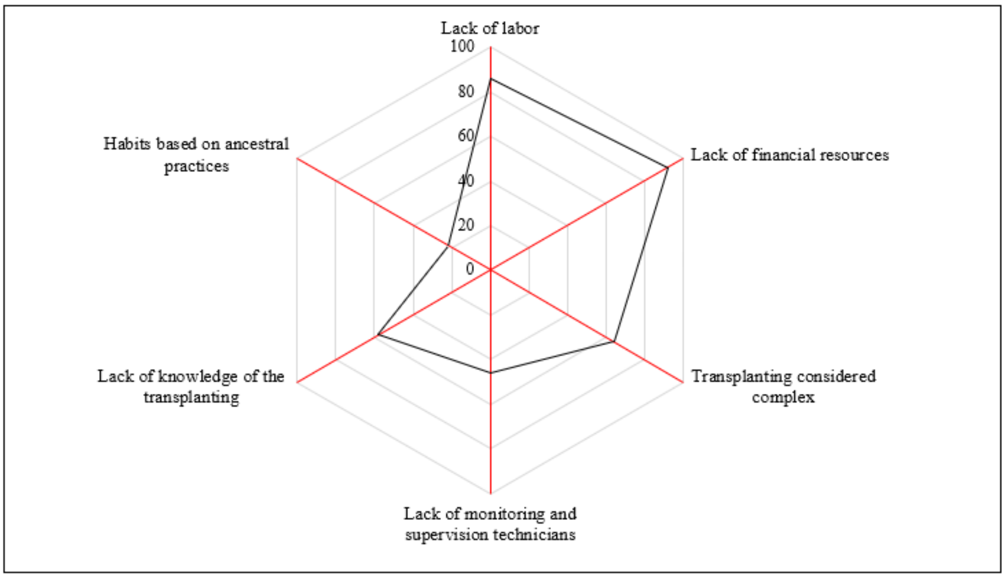

Figure 6: Constraints of Transplanting adoption

Effects of location on paddy rice yield

The yield mean of data collected in all sites was calculated at the 95% confidence interval with and standard error. Analysis of these means showed that location had no significant effect on rice yields in similar conditions of the experiment (Table 1). However, although the observed difference was not significant, Kagnikada farmers recorded the highest yield, while the lowest yield was obtained at the Sirka site.

Table 1: Effects of location on paddy rice yields

Location	Paddy rice yields (t/ha)
Kagnigada	3.00 ± 0.61 a
Lidao	2.97 ± 0.72 a
Tchade - Lemde	2.71 ± 0.78 a
Farende	2.66 ± 0.67 a
Sirka	2.41± 0.70 a
p-value	0.159
cv%	19.91
LSD (α < 0.05)	0.71

Effects of sowing method on paddy rice yield and milled rice quality

The sowing method significantly influenced the rice yields. The Duncan comparison test at the 5% threshold revealed the existence of distinct homogeneous classes between the three seeding methods. The transplanting method induced the highest yield (3.26 t/ha), while the yield under the direct seeding method was statistically intermediate to both rice yields (Table 2). The results show that the average gain compared to broadcast seeding was 47.51% and 25.33 % for transplanting and direct seeding methods, respectively.

The sowing method had a significant effect on milled rice quality. As indicated in Table 2., the comparison test at the 5% threshold showed that the milled rice long grain rate was lowest (48.99 %) and the milled rice breakage rate under the broadcast seeding method was highest (51.01 %).

Compared to the transplanting method, the gap was around 5% and 1% from the direct and broadcast seeding methods, respectively.

Table 2: Effects of sowing method on paddy rice yield and milled rice quality

Sowing method	Paddy rice yields (t/ha)	Milled rice long grain rate (%)	Milled rice breakage rate (%)
Transplanting	3.26 ± 0.17a	55.99 ± 0.04a	44.01 ± 0.06c
Direct seeding	2.77± 0.11ab	55.03 ± 0.07b	44.97 ± 0.27b
Broadcast seeding	2.21 ± 0.15b	51.01 ± 0.06c	48.99 ± 0.01a
p-value	7.21e-05***	8.97e-09 ***	2.26e-08 ***
cv%	19.91	0.059	0.972
LSD, (α<0.05)	0.86		

Effects of sowing methods on rice farmers' profitability

Labor costs, agricultural inputs costs, and profit among the three sowing methods were estimated through the operating accounts (Table 3). The broadcast seeding method observed the lowest production cost (460 $USD /ha). Compared to direct seeding and broadcast seeding, the transplanting method increased the cost of production by 19.95% and 55.87%, respectively. The transplanting method increased direct and broadcast seeding labor costs by 38% and 64.26%, respectively. In addition, the cost of the inputs (seeds, herbicides, fertilizers) under the transplanting method was 11.11% and 14.29% less in the case of direct seeding and broadcast seeding, respectively. However, the highest gross margin was achieved in the transplanting method (1,146 $USD/ha). Compared to direct seeding and broadcast seeding, the transplanting method improved the gross margin of farmers at 72.85% and 165.89%, respectively. The benefit/cost ratio was 1.6 for the transplanting method, 1.1 for the direct seeding method, and 0.9 for broadcast seeding methods. As a result, the transplanting method was as profitable as the other two methods.

Table 3: Operating account of the various seeding methods

No.	Operations	Transplanting ($UDS)	Direct seeding ($UDS)	Broadcast seeding ($UDS)
1	Recipe			
1.1	Long grain	1,223	816	543
1.2	Broken rice	641	445	348
	Total recipe	1,864	1,261	891
2	Cost			
2.1	Inputs cost (seeds, herbicides, fertilizers)	144	160	168
2.2	Equipment costs (sicklewood, cut, Pulver, bags, hoe, cord, etc.)	129	90	69
2.3	Labour costs (tillage, fertilizer application, transplanting, manual weeding, harvest, transport, etc.)	294	213	179
2.4	Post-harvest operation costs (winnowing, sorting, machining, bagging, etc.)	152	135	45
	Total costs	718	598	460
	Gross margins	1,146	663	431
	BCR	1.6	1.1	0.9

DISCUSSION

Socioeconomic aspects and sowing methods practiced by rice growers

As the results showed, the women rice growers were all widowed except one. So, their low proportion of rice farming can be explained by the fact that men are the main household managers, and women generally only become heads of a household when their husbands die or divorce (DSID, 2013). Also, it should be noted that men have more of a monopoly on access to land and therefore own most rice farms (MAEP, 2010). Thus, women and children constitute a labor force for the agricultural activities of the head of the household, who is the man, and consequently cannot own their own farms. This would justify why women are less interested in rice cultivation.

The transplanting was low adopted by the rice growers at a rate of 14%. This low rate for transplanting adoption compared to other sowing methods can be justified by lack of agricultural credit, unavailable family labor, lack of on-farm demonstration and ignorance of transplanting profit, etc. According to several authors (Shriwas *et al*., 2019; Udimal *et al*., 2017), rice technology adoption is influenced by: growers' education level, credit access, on-farm demonstration, family labor, and profit orientation of the farmers. In India, a study showed that the labor shortage was one of the major constraints rice farmers face in adopting agricultural technologies at 80% (Karangami *et al*., 2019). According to Kaur and Singh (2017), labor scarcity during peak periods was one of many constraints of transplanting method adoption and direct sowing, and the oldest method is gaining popularity because of its low-input demand.

The maximum education level of rice growers is primary school, and the area of 90% of plots was more than one hectare. This makes it difficult to adopt transplanting due to a lack of agricultural labor and transplanting mechanization. Addison *et al*. (2022) showed that education and farm size inhibit the selected technologies' uptake.

the results of this study showed that the adoption rate among women is higher than that of men. So, women are more supportive of new technology than men, unlike Addison *et al*. (2022), who found that female inhibits the uptake of the selected technologies. Adoption constraints of transplanting mentioned by the rice growers corroborate with Dendup *et al*. (2018), who showed that direct seeding or broadcasting compared to transplanting, required less labor and rice production cost. Further, In India, rice growers expressed a lack of knowledge and complicated practices as technological constraints by 73% and 69%, respectively (Balamurugan & Rajasekaran, 2019).

Effects of sowing methods on paddy yields, milled rice quality and profitability

The study results showed that the transplanting method induced paddy yields (3.26 t/ha) to half the potential of the IR841 variety (6 t/ha) as demonstrated by Adomefa *et al.* (2007). In the same way, several authors showed that transplanting improved paddy yields (Troy & Picaud, 2013; Bhuyan *et al*., 2012; Krupnik *et al*., 2012; Ehsanullah *et al*., 2007). On the other hand, Rana *et al.* (2014) showed that the highest rice yield was obtained with the direct seeding method.

The rice sowing method significantly influenced the milled rice. The highest milled rice quality was obtained through the transplanting method. Similarly, Nessreen *et al.* (2019) showed that the milling characters as 1,000-grain weight from the transplanting method were high compared to broadcasting. Likewise, the transplanting method induced high rice milled quality as the husking grain ratio, length, and width value (Abou-Khalifa *et al*., 2021).

The results showed that the labor cost under the transplanting method was the highest, and the input cost was the lowest. Similar findings were recorded as labour requirements and costly input costs were mentioned by Parte *et al.* (2019). Nevertheless, the production cost induced by the transplanting method in this study (19.95% and 55.87% compared to direct seeding and broadcast seeding, respectively) was lower than 53% and 42% under direct seeding and broadcasting methods (Dendup *et al*., 2018). Economic analysis of input costs and recipes under various sowing methods showed that the transplanting method improved the framers' income better than direct sowing and broadcast sowing methods. If this study revealed that the farmers' gross margin under the transplanting method was improved at 19.95% and 55.87% compared to direct seeding and broadcast seeding, Parte *et al.* (2019) indicated that the gain was at 4.9% and 45.31%. On the contrary, Chen *et al.* (2020) revealed that the direct seeding method did not increase paddy yield compared to the transplanting method but significantly improved economic profit. The benefit-cost ratio under the transplanting method (BCR = 1.6) and direct sowing (BCR = 1.1) greater than 1 showed that both the technologies were economically feasible options contrary to the broadcast sowing method whose BCR was lower than 1 (Razzaq *et al*., 2018). Then, the transplanting method is a more sustainable sowing method than the sowing methods.

CONCLUSION

This research first studied the adoption constraints of the transplanting method in rainfed rice and secondly showed the effect of the seeding method on the rice yield and milled rice quality. Thus, the transplanting method, compared to direct seeding and broadcast seeding methods, was not adopted by most rice farmers due to its labor requirements and high production costs. However, the transplanting method increased the paddy rice yield and the milled rice quality through the low broken rice rate. In addition, the farmers' incomes could be improved using the transplanting method. Moreover, although the rice farmers' profit under the transplanting method was the highest, direct seeding was also profitable. This study did not focus on water management at the plot level, the physicochemical characteristics of the soil (e.g., organic matter, fertility, texture, etc.), or rice grain humidity before and after hulling. In perspective, research must be conducted to reduce labor costs in rice transplanting method in order to improve the income of rice farmers.

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REFERENCES

Abdulai, S., Zakariah, A. & Donkoh, S.A. (2018). Adoption of rice cultivation technologies and its effect on technical efficiency in Sagnarigu District of Ghana. *Cogent Food & Agriculture, 4*, 1424296; https://doi.org/10.1080/23311932.2018.1424296

Abou-Khalifa, A.A., Ziden, A.A., Elshenawy, M.M. & Hassan, H.M. (2021). Effect of Planting Methods and Cultivars on Rice Grain Quality. *Plant Production, Mansoura Univ., 12*(11), 1247 – 1254.

Addison, M., Ohene-Yankyera, K., Acheampong, P.P. & Wongnaa, C.A. (2022). The impact of uptake of selected agricultural technologies on rice farmers' income distribution in Ghana. *Agric & Food Secur., 11*(2). https://doi.org/10.1186/s40066-021-00339-0

Adomefa, K., Agbobli, C.A. & Labare K. (2007). Reference situation on the main cereals grown in Togo. *ITRA,* 107.

Arouna A., Fatognon I.A., Saito K. & Futakuchi K. (2021). Moving toward rice self-sufficiency in sub-Saharan Africa by 2030: Lessons learned from 10 years of the Coalition for African Rice Development. *World Development Perspectives, 21*, 10029.

Arsil P., Tey Y.S., Brindal M., Eni A. & Masrukhi S. (2022). Perceived attributes driving the adoption of system of rice intensification: The Indonesian farmers' view. *Open Agriculture, 7*, 217–225. https://doi.org/10.1515/opag-2022-0080

Balamurugan, V. & Rajasekaran R. (2019). A study on constraints experienced by the farmers in adoption of system of rice intensification (SRI) technologies. *Plant Archives, 19*(1), 1902-1904.

Balasubramanian V., Sie M., Hijmans R. J. & Otsuka K. (2007). Increasing rice production in Sub-Saharan Africa: challenges and opportunities. *Advances in Agronomy, 94*, https://doi.org/10.1016/S0065-2113(06)94002-4

Bassuony, N. N., & Zsembeli, J. (2019). Effect of planting methods on the quality of three Egyptian rice varieties. Agriculture, 65(3), 119-127. https://doi.org/10.2478/agri-2019-0012

Bhuyan, M. H. M., Ferdousi, M., & Iqbal, M. T. (2012).

Yield and growth response to transplanted aman rice under raised bed over conventional cultivation method. *International Scholarly Research Notices, 2012*. https://doi.org/10.5402/2012/646859

Bian J.L., Xu F.F., Han C., Qiu S., Ge J.L., Xu J., Zhang H.C., Wei H.Y. (2018). Effects of planting methods on yield and quality of different types of japonica rice in northern Jiangsu plain, China. *Journal of Integrative Agriculture, 17*(12), 2624–2635.

Yu-Tiao, C., Jia-Yu, S., Yan, C., Guang-Long, Z., & Xiao-Fu, H. (2020). Comparison of yield performance and rice quality between direct-seeded and hand-transplanted rice under different nitrogen rates in Eastern China. *African Journal of Agricultural Research, 16*(6), 875-883. https://doi.org/10.5897/AJAR2020.14830

Dendup C., Chhogyel N., Ngawang N. (2018). Effects of different planting methods on rice (Oryza sativa L.) crop performance and cost of production. *Bhutanese Journal of Agriculture, 1*(1), 13-22.

Dianga A., Musila R. N. & Joseph. K. W. (2021). Rainfed Rice Farming Production Constrains and Prospects, the Kenyan Situation. *Integrative Advances in Rice Research*. http://dx.doi.org/10.5772/intechopen.98389

Donkoh S.A., Azumah S.B. & Awuni A.A. (2019). Adoption of Improved Agricultural Technologies among Rice Farmers in Ghana: A Multivariate Probit Approach. *Ghana Journal of Development Studies, 16*(1), http://dx.doi.org/10.4314/gjds.v16i1.3

DSID, (2013). General overview of Togolese agriculture. *Recensement national de l'agriculture du Togo, 2011-2014, 1*, 122.

Ehsanullah, N.A., Jabran K. & Habib T. (2007). Comparison of different planting methods for optimization of plant population of fine rice (Oryza sativa L.) in Punjab (Pakistan). *Pak. J. Agri. Sci. 44*(4), 597-599.

Faure P. (1985). Les sols de la Kara (Nord-Est-Togo), relation avec l'environnement. 183, édition de l'O.R.S.T.O.M, 281.

Graham-Acquaah S., Saito K., Traore K., Dieng I., Alognon A., Bah S., Sow A. & Manful J.T. (2018). Variations in agronomic and grain quality traits of rice grown under irrigated lowland conditions in West *Africa. Food Sci Nutr. 6*, 970–982. www.foodscience-nutrition.com, http://dx.doi.org/10.1002/fsn3.635

Guibert H., Kueteyim PK., Bassala J-PO. & M'Biandoun M. (2016). Intensifier la culture du maïs pour améliorer la sécurité alimentaire : le producteur du Nord Cameroun y a-t-il intérêt ? *Cahiers Agricultures, 25*(6), 65006.

Ilieva V., Markova Ruzdik N., D. Vulcheva, Mihajlov Lj. & Ilievski M. (2019). Effect of harvest time of paddy on milled rice yield and broken kernels. *Agricultural science and technology, 11*(4), 327-331. http://dx.doi.org/10.15547/ast.2019.04.055

John A. & Fielding M. (2014). Rice production constraints and 'new' challenges for South Asian smallholders: insights into de facto research priorities. *Agriculture & Food Security, 3*, 18. http://www.agricultureandfoodsecurity.com/content/3/1/18

Kahimba, F.C., Kombe, E.E., & Mahoo, H.F. (2014). The Potential of System of Rice Intensification (SRI) to Increase Rice Water Productivity: a Case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania. *Tanzania Journal of Agricultural Sciences (2014), 12*(2), 10-19.

Karangami R. S., Dhenge S. A., Yadav S. V. & Mehta P. G. (2019). Constraints Faced by Rice Growers in Adoption of Recommended Rice Cultivation Practices in Palghar District of Maharashtra, India. *Int. J. Curr. Microbiol. App. Sci. 8*(10), 682-685. Short Communications. https://doi.org/10.20546/ijcmas.2019.810.077

Kaur J. & Singh A. (2017). Direct Seeded Rice: Prospects, Problems/Constraints and Researchable Issues in India. *Current Agriculture Research Journal, 5*(1), 13-32. http://dx.doi.org/10.12944/CARJ.5.1.03

Krupnik T. J., Shennan C., Settle W. H., Demont M., Ndiaye A. B. & Rodenburg J. (2012). Améliorer la production du riz irrigué dans la Vallée du Fleuve Sénégal à travers l'innovation et l'apprentissage par l'expérience. *FAO*, 28.

Laignelet, B. & Marie R. (1983). Fluctuation de la qualité technologique du riz en fonction du génotype et du milieu. *Agronomie, EDP Sciences, 3*(2), 179-183.

MAEH (2016). Plan de développement de la filière riz au Togo. *Rapport, 40*.

MAEH (2015). La politique agricole assortie du plan stratégique pour la transformation de l'agriculture au Togo à l'horizon 2030 (PA-PSTAT 2030) - Document de politique agricole pour la période 2016-2030, 56.

Parte J., Rathi D., Patel M., & Pandey S. (2019). Economics of Paddy Cultivation under Different Sowing Techniques in Raipur District of Chhattisgarh. *Int. J. Curr. Microbiol. App. Sci. 8*(12), 693-699. https://doi.org/10.20546/ijcmas.2019.812.091

Prom-u-thai C. & Rerkasem B. (2020). Rice quality improvement. *Agronomy for Sustainable Development, 40*, 28. https://doi.org/10.1007/s13593-020-00633-4

Rana M. M., Al Mamun M. A., Zahan A., Ahmed M. N. & Mridha M. A. J. (2014). Effect of Planting Methods on the Yield and Yield Attributes of Short Duration Aman Rice. *American Journal of Plant Sciences, 5*, 251-255; http://dx.doi.org/10.4236/ajps.2014.53033

Rashid M.H., Rony M.K.I., Mahalder D. & Goswami P.C. (2019). Adoption of improved production practices in low-land rice through community training. *SAARC J. Agric., 17*(1), 1-11. https://doi.org/10.3329/sja.v17i1.42757

Shriwas Y., Awasthi HK, Shrivastava KK & Verma AK. (2019). Constraints faced by the rice growers and their suggestions to overcome the constraints in the adoption of farm machinery in Chattisgarh plains. *Journal of Pharmacognosy and Phytochemistry, 8*(1), 1139-1142.

Sorkpor R. D. (2015). Effect of training in good rice (Oryza sativa) cultivation and postharvest practices on quality of milled rice produced in the Ahafo Ano north district, Ashanti region. A thesis submitted to the school of research and graduate studies, Kwame Nkrumah university of science and technology, Master of Philosophy (postharvest technology) degree, 119.

Razzaq, A., A. Rehman, A.H. Qureshi, I. Javed, R. Saqib, & Iqbal M.N. (2018). An economic analysis of high efficiency irrigation systems in Punjab, Pakistan. *Sarhad Journal of Agriculture, 34*(4), 818-826. http://dx.doi.org/10.17582/journal.sja/2018/34.4.818.826

Overview of aTroy B. & Picaud C. (2013). Better water management through innovative agricultural practices: what prospects in developing countries? A review of experiences with direct seeding on cover crops (SCV), system of rice intensification (SRI), zai and drip irrigation. Working document n°1, 70, Togolese agriculture pages.

Uddin M.J., Ahmed S., Harun-or-Rashid M., Hasan M. M. & Asaduzzaman M. (2011). Effect of spacings on the yield and yield attributes of transplanted Aman rice cultivars in medium lowland ecosystem of *Bangladesh. J. Agric. Res., 49*(4).

Udimal T.B., Jincai Z., Mensah O.S., Ayamba E.C. (2017). Factors Influencing the Agricultural Technology Adoption: The Case of Improved Rice Varieties (Nerica) in the Northern Region, Ghana. *Journal of Economics and Sustainable Development, 8*(8), 2222-2855.

Yovo K. (2010). Price incentives, profitability and competitiveness of rice production in southern Togo. *Tropicultura, 28*(4), 226-231.