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Exploring the Impact of Yam Minisett Technology Adoption on the Income and Technical Efficiency of Yam Producers in Nigeria

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Abstract

The yam minisett technique (YMT), designed to address the shortage of seed yams, has been widely adopted by farmers compared to other scientifically enhanced yam propagation methods. Yet, there remains a dearth of information regarding how its adoption impacts farmers' productivity. This study examined the impact of YMT adoption on the income and technical efficiency of yam producers in Nigeria. A multistage sampling technique was used to collect primary data from 120 farmers with the aid of a structured questionnaire. Data were analyzed using stochastic frontier and propensity score matching. Results revealed that gender, educational level, household size, adoption, and extension contact significantly influenced the technical efficiency of yam producers. The adoption of YMT had a significant effect on the technical efficiency and income of yam producers. Adopters and non-adopters had mean technical efficiency of 97% and 96% respectively however non-adopters had lower minimum individual technical efficiencies. It is recommended that the adoption of the yam minisett technology should be encouraged among farmers in Nigeria because of its potential to enhance their technical efficiency and income levels. The government should ensure that there is a provision of adequate planting materials for yam minisett technology as a measure to encourage the adoption of crop technologies.

Keywords: Adoption, Yam Minisett Technology (YMT), Technical efficiency, Average Treatment Effect, Stochastic Frontier, Farmers' Income

INTRODUCTION

Yam, scientifically known as Dioscorea rotundata and commonly referred to as white yam, is a tuber crop of the Dioscoreaceae family and is predominantly cultivated in West Africa (Adigoun-Akotegnon et al., 2019). According to FAOSTAT (2014), global yam production in 2012 reached approximately 58.7 million tons, with over 92 percent originating from West Africa. Nigeria and Ghana jointly contribute around 66 percent of the world's total yam output. Yam being a staple food, plays a vital role in providing both income and dietary carbohydrates to millions of people (Obidiegwu et al., 2020). Its extended dormancy period makes it more preservable compared to other tropical root crops, enhancing its significance as a food security crop (Sugri et al., 2021).

Despite the substantial yam production in West Africa, there is a notable absence of a formal seed yam production or marketing system to cater to farmers' needs (Almekinder et al., 2019). FAOSTAT (2014) estimates the quantity of seed yams required for planting fields in Nigeria and Ghana to be between 7 to 10 million tons. In Nigeria particularly, many farmers either inherit, purchase, or receive seed yams as gifts, reflecting the informal nature of the seed yam supply chain (Komolafe, 2018). Yam production faces significant challenges due to its low multiplication rate, which makes expanding production areas difficult. The high cost of seed yam further exacerbates this issue, leading to limited availability of affordable and high-quality planting material (Aidoo et al., 2011).

Consequently, literature often attributes low productivity to the persistent problem of inadequate seed yam supply (Andsumugha and Ogbona, 2013). Farmers commonly resort to repeatedly multiplying seed yams, resulting in diminished productivity over time due to continuous exposure to pests and diseases (Pelemo, 2021). In Nigeria, urban areas are experiencing rising yam prices, rendering yam relatively unaffordable as production struggles to keep pace with population growth. This imbalance between demand and supply is primarily attributed to the high cost of seed yam, which constitutes 45% of yam production expenses (Babatunde, 2020). Other challenges facing yam production include weed infestation, soil-borne pests and diseases, leaf diseases, declining soil fertility, high labor costs for land preparation, scarcity of staking materials, and reliance on traditional production techniques. Additionally, consumer preferences play a role in shaping production challenges in the yam industry (Musa et al., 2023).

Traditional yam cultivation practices in Nigeria present farmers with significant challenges, including high expenses and difficulties in obtaining planting materials. Consequently, farmers often reserve a portion of their yam harvest for replanting in the next season. This necessity limits the number of yams available for sale or family consumption. To address these issues, the innovative Yam Minisett Technique (YMT) was developed. (Mignouna et al. 2013). The adoption of modern agricultural practices such as the YMT indicates the extent to which farmers integrate this new technology into their long-term operations, informed by a comprehensive knowledge of the technology and its potential benefits. (Adofu, 2013). The minisett technology was first introduced to farmers as far back as 1993, but there was no significant adoption of the technique until 2003. The introduction of the yam minisett technology is one of the efforts aimed at boosting yam production. Since the tuber is the planting material as well as the edible part, the minisett technology provides planting materials so that the farmer would not worry about what to plant the next season (Agbarevo, 2014). The yam minisett technology offers a swift supply of seed yams and aims to address the challenge of seed yam scarcity, a significant barrier to scaling up yam production contrary to the traditional yam cultivation method (Nwankwo et al., 2023).

The importance of this improved agricultural technology (yam minisett) has been numerous, but its adoption based on socioeconomic determinants has not received much empirical attention. Ayoola (2013) highlights a noteworthy correlation between farmers' socioeconomic attributes and their adoption of enhanced technology, specifically the yam minisett technology. These socioeconomic characteristics pertain to the individual predispositions of farmers or decision-makers who determine whether to adopt or not adopt such innovations (Tey and Brindal, 2013). Developing mini-sett production and distribution networks for staple crops like yam would represent a proactive approach, particularly given the current fluctuations in environmental and climatic conditions. YMT has the potential to mechanize operations, remove the need for stakes, and reduce the amount of planting materials required for yam cultivation (Aighewi et al., 2014).

The concept of technical efficiency in agriculture stems from production efficiency theory, which denotes a farmer's capacity to attain the maximum output possible from a specific set of inputs (Coelli et al., 2005; Chandio et al., 2019). It is commonly believed that adopting innovative agricultural technologies, such as the yam minisett technique, can improve both technical efficiency and farmers' income by optimizing input utilization and boosting crop yields. However, the extent to which yam minisett technology adoption affects the technical efficiency, productivity, and income of yam producers in Nigeria remains a matter of great interest and has not been fully explored in literature. Therefore, this study sought to examine the impact of the adoption of yam minisett technology on the technical efficiency and income of yam producers in Nigeria. Specifically, the study assessed the technical efficiency of adopters and non-adopters of yam minisett technology and explored the impact of yam minisett technology adoption on farmers' income.

Literature Review

Theoretical Framework

Adoption And Diffusion Perspectives

Adoption can be understood as an individual journey encompassing the stages from initial awareness of a product to its full integration into one's practices. Rogers (2010) stated that adoption is a conscious choice to embrace an innovation or technology as the most beneficial option available. He also introduced the concept of adopters' categories, indicating that a certain portion of the population readily adopts an innovation while others are less inclined to do so. This categorization is significant as it highlights the natural, predictable, and sometimes gradual progression of innovations within a population. Rogers observed that adopter categories typically follow a bell-curve distribution.

The theory of diffusion of innovation, as articulated by Rogers (2010), aims to elucidate how, why, and at what pace new ideas and technologies disseminate across cultures. Diffusion is described as the process through which an innovation spreads over time among members of a social system, facilitated by specific communication channels. Ekong (2003) identified four primary elements influencing this spread: the innovation itself, communication channels, time, and social systems. Human capital plays a crucial role in this process, as widespread adoption is essential for the innovation to become self-sustaining.

Empirical Framework

Many studies have investigated yam minisett technology adoption and its influence on the technical efficiency of yam producers. A study by Ibitoye et al. (2013) revealed key social and economic factors influencing yam minisett adoption by farmers. These factors include age, gender, education level, participation in farmer associations, and family size. Studies, like one by Achoja et al. (2012), have shown a positive correlation between yam minisett technology adoption and a farmer's net income. However, a major barrier to wider adoption exists. Many yam producers, particularly in Nigeria, are low-income earners and small-scale farmers with limited or no access to credit facilities. This financial constraint restricts their ability to invest in technology.

A study by Ibitoye (2013) revealed inefficiencies in both adopters and non-adopters of yam minisett technology. Adopters improved efficiency by using more labor, yam minisetts, extension service contact, and higher education. For non-adopters, factors like farm size, labor, education, and extension contact boosted efficiency. Nweke et al. (2002) found that adopters of yam minisett technology experienced higher yields and greater efficiency levels compared to non-adopters. The study attributed these gains to the technology's ability to ensure a more reliable supply of healthy planting materials and reduce losses from pests and diseases. Similarly, Aighewi et al. (2015) in their research on yam minisett technology in West Africa reported significant improvements in yam productivity and farm-level efficiency among adopters. The study emphasized the role of extension services and farmer training in enhancing the adoption rates and effectiveness of the technology. In the study conducted by Omotesho et al. (2012), there was a positive correlation between the adoption of this technology and the overall technical efficiency of the farms. Adopters of the minisett technology had significantly higher efficiency scores compared to non-adopters. Olatinwo et al. (2022) highlighted that the adoption of yam minisett technology led to an increase in yam yields due to more efficient use of inputs and a reduction in yam seedling mortality rates.

METHODOLOGY

Study area

Abuja is the capital with its slogan "Center of Unity" and the eighth-most populous city of Nigeria. "It is situated in the heart of Nigeria as the Federal Capital Territory (FCT) and shares borders with Niger State to the west and northwest, Kaduna to the northeast, Nasarawa to the east and south, and Kogi to the southwest". Positioned at Latitude 9.0765° N and Longitude 7.3986° E, the city serves as the administrative center of the nation. "The Federal Capital Territory consists of six councils: Abaji, Abuja Municipal, Bwari, Gwagwalada, Kuje, and Kwali" (Fig 1).

The Federal Capital Territory (FCT) undergoes three distinct weather patterns throughout the year. These consist of a scorching dry season, a warm and humid rainy season, and a short interval of harmattan induced by the northeast trade wind. The Harmattan period is characterized by dust haze and dry conditions. In terms of agriculture, the FCT predominantly cultivates crops such as maize, sorghum, groundnut, cassava, yam, and various other crops such as garden egg, pepper, and okra.

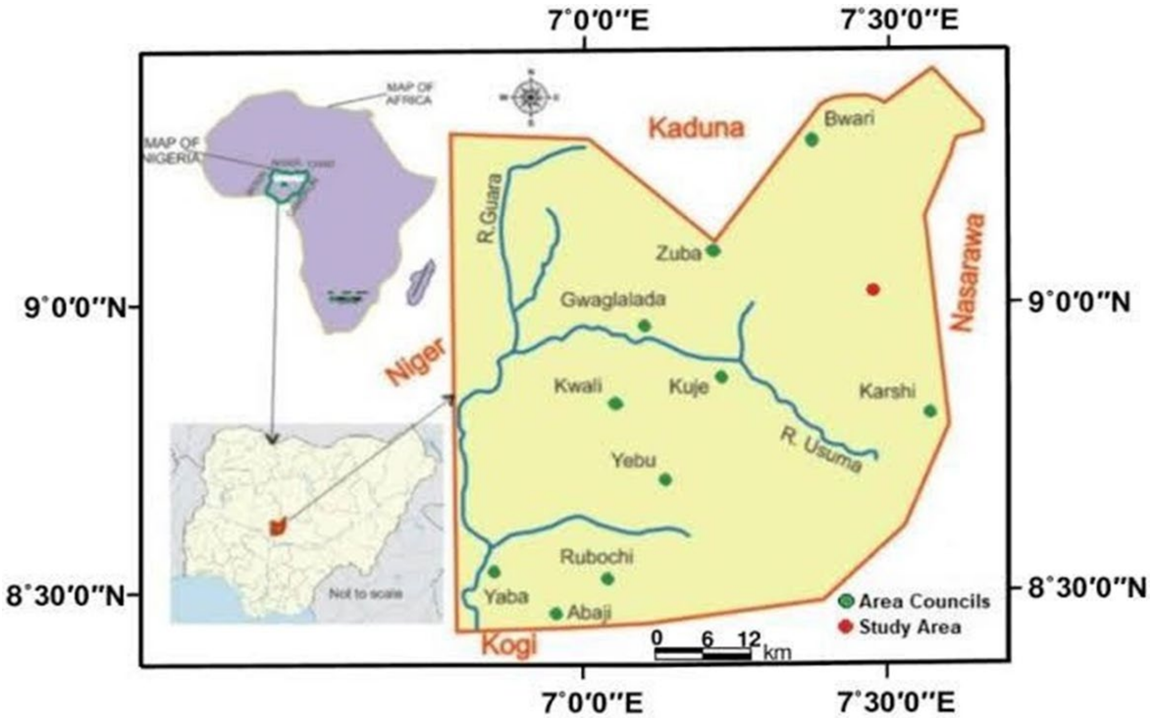

Fig 1: Map of the Federal Capital Territory, Abuja showing the various councils

Sampling techniques

The study employed a multistage sampling technique of which the first stage involved the purposive selection of 3 councils majorly known for a high level of yam farming activities. The second stage involved randomly selecting five (5) villages from each council. In the last stage, eight (8) farmers were randomly selected from each village making a total of 120 yam producers.

Data collection

The data for the study were collected with the aid of a well-structured questionnaire. The questionnaire was written in English and was read to the non-educated farmers.

Data analysis

The data collected were analyzed using the following statistical tools.

Descriptive Statistics

Descriptive statistics such as frequency and percentage were used to depict the relevant socio-demographic characteristics of the respondents.

Stochastic Frontier

The Cobb-Douglas functional form of the stochastic frontier model was used to assess the technical efficiency of both adopters and non-adopters of yam minisett technology (YMT). This model offers the advantage of promptly estimating farmers' individual technical efficiencies and identifying the factors influencing these efficiencies (Ng'ombe, 2017). The model in its linearized form is expressed as

$$lnY = \beta 0 + \beta 1 lnX1 + \beta 2 lnX2 + \beta 3 lnX3 + \beta 4 lnX4 + \beta 5 lnX \ldots\ldots\ldots\ldots \quad (1)$$

Where: Y = output of yam producers (kg), X1= Cost of planting materials, X2 = yam seed (kg), X3 = Fertilizer (kg), X4 = Cost of herbicides, X5 = Labour (man-day)

β0 to β5 are the parameters to be estimated.

The inefficiency model is represented by Ui which is defined as follows:

$$ui = d0 + d1Z1 + d2Z2 + d3Z3 + d4Z4 + d5Z5 + d6Z6 \ldots\ldots\ldots\ldots \quad (2)$$

ui = Technical inefficiency

Z1 = Level of education (1 = Formal education, 0 = Otherwise)

Z2 = Household size

Z3 = Age (years)

Z4 = Extension contacts (1 = Yes, 0 = Otherwise)

Z5 = Member of cooperative (1 = Yes, 0 = Otherwise)

Z6 = Gender (1 = Male, 0 = Otherwise)

d0 to d6 are the parameters to be estimated.

In the inefficiency model, the dependent variable denotes the level of inefficiency. Therefore, a positive coefficient for an estimated parameter indicates that the corresponding variable negatively impacts efficiency, and conversely, a negative coefficient suggests a positive effect on efficiency. (Rhaji, 2005).

Propensity Score Matching

The Propensity Score Matching (PSM) was used to determine the effect of the adoption of YMT on farmers' income. Propensity Score Matching (PSM) involves the pairing of treatment and control groups based on similar propensity score values.

This is given as;

$$ATE = E(Y_1 D = 1) - E(Y_0 D = 0) \ldots\ldots\ldots\ldots \quad (3)$$

Where treatment D is given as a binary variable if the minisett technology increases income or otherwise. D = 1 for increased income while D = 0 for otherwise.
Y_1 represents the outcome value for a household that has adopted the technology (1), while Y_0 indicates the outcome value for the same household when it has not adopted the technology (0).

RESULTS AND DISCUSSION

Socioeconomic and demographic characteristics of respondents

Results (Table 1) revealed that majority (38.96%) of the adopters were more than 60 years. Similarly, most (45.24%) of the non-adopters are more than 60 years. This portrays that most of the adopters and non-adopters of YMT are not in their active years but are super productive and they put in their best efforts and resources. Ayoade (2013) reported that labor was not a disadvantage as most of the farmers were able-bodies and actively involved in farming activities. More than two-thirds (87.01%) of the adopters were males. In the same vein, more than two-thirds (85.71%) of the non-adopters were males. This conforms to the results of Lawal et al. (2014) who reported that most farmers are male implying that they can do tedious farm work.

Results showed that 88.31% and 95.24% of adopters and non-adopters had some level of formal education respectively in the form of primary, secondary, or tertiary education. This could easily afford them the ability to understand the concept of the technology if well demonstrated to them. Ayoade, (2012) posited that education helps in adopting improved agricultural technologies. Majority of the adopters and non-adopters were married implying that most respondents are saddled with family responsibilities according to the findings of Lawal et al (2014). Results further revealed that about half of the number of adopters and non-adopters had household sizes had 6-10 members in their households indicating fairly large family members among respondents. More than half of the adopters and non-adopters had spent above 35 years in the yam farming business implying that they have been in the business for a long time and are well experienced in managing their farming activities. Adopters and non-adopters earn above 300,000 naira (USD 192) implying that most of the respondents are able to generate a fair amount of revenue from their yam farming enterprise. This harmonizes with the findings of Omoregbee and Edeogbon (2006) who observed that farming serves as the primary source of income for 90% of impoverished households in rural regions.

Most of the adopters and non-adopters do not belong to any cooperative society. In the same vein, most of the two categories of yam producers do not have any access to credit. This might hamper increased productivity and profit efficiency due to the unavailability of funds for business expansion. Zeller et al. (2006) reported that access to credit helps to boost productivity amongst farmers. Most (79.22%) of the adopters and majority (90.48%) of the non-adopters had access to extension services indicating that farmers have access to quality information about new agricultural innovations. This is in line with the findings of Shiferaw et al. (2008) who noted that farmers receiving regular visits from extension agents tend to show more progressive attitudes and a higher willingness to try out yam minisett technology. Most (37.66%) of the adopters are engaged in yam cultivation using community land while majority (40.48 %) of the non-adopters owned their land through inheritance. Adopters might feel a sense of land security for smooth operation based on the communal land system type. In terms of farm size, more than two-thirds of adopters and non-adopters had farm sizes of less than 5 hectares. Manjunatha et al. (2015) reported that small farmland negatively affects agricultural productivity.

Table 1: Socioeconomic and demographic characteristics of respondents

	ADOPTERS (N = 77)		NON-ADOPTERS (N = 43)	
Variables	Frequency	Percentage	Frequency	Percentage
Age				
>30	1	1.30	0	0
31-40	5	6.49	7	16.67
41-50	24	31.17	8	19.05
51-60	17	22.08	8	19.05
Above 60	30	38.06	20	45.24
Gender				
Male	67	87.01	37	85.71
Female	10	12.99	6	14.29
Educational Level				
No formal Education	9	11.69	2	4.76
Primary Education	24	31.17	21	47.62
Secondary Education	29	37.66	17	40.48
Tertiary Education	15	19.48	3	7.14
Marital Status				
Single	0	0	2	4.76
Married	6	89.61	36	83.33
Divorced	3	3.90	3	7.14
Widowed	5	6.49	2	4.76
Household size				
≤ 5	32	41.56	15	33.33
6-10	38	49.35	21	50.00
Above 10	7	9.09	7	16.67
Years of farming Experience				
6-15	3	3.90	1	2.38
16-25	14	18.18	5	11.09
26-35	10	12.99	7	16.67
Above 35	50	64.94	30	69.05
Extension contacts				
Yes	61	79.22	39	90.48
No	16	20.78	4	9.52
Membership of cooperative				
Yes	24	31.17	13	30.95
No	53	68.83	30	69.05
Access to credit				
Yes	20	25.97	11	26.19
No	57	74.03	32	73.81
Land ownership				
Inheritance	23	29.87	18	40.48

Lease	6	7.79	3	7.14
Rent	6	7.79	5	11.90
Acquired	13	16.88	6	14.29
Community land	29	37.66	11	26.19
Farm Size (hectares)				
≤ 5	67	87.01	35	80.95
6-10	10	12.99	8	19.05
Income (naira)				
50-100,000	1	1.30	0	0
101-200,000	1	1.30	4	9.52
201-300,000	3	3.90	3	7.14
Above 300,000	72	93.51	36	83.33

Determinants of the Technical Efficiency of Yam Producers

Results (Table 2) revealed that the number of planting materials and labour cost positively and significantly influence yam production implying that one unit increase in the number of planting materials results in 0.796 increases in yam output in kg and an increase in labour cost by one unit will lead to 0.948 increases in yam output in kg. This is not in line with apriori expectations, because an increase in the cost of labour is expected to reduce productivity. It contradicts the findings of Nguyen-Thi-Lan et al. (2023) who revealed that labor cost had a positive significant effect on the output of crop production. Furthermore, the cost of herbicide was negatively significant which means that an increase in the cost of herbicide led to a reduction in yam output implying that productivity is enhanced when less cost is incurred to procure inputs such as herbicides. Munezero et al. (2023) similarly reported that the cost of weeding and pesticides had a positive influence on crop output.

The inefficiency model presented shows that factors such as adoption, gender, educational level, household size, and extension contact significantly influenced the technical inefficiency of yam producers. Gender had a negative coefficient indicating that male farmers bring about decreased inefficiency and are more technically efficient than their female counterparts. Education level was found to negatively influence technical inefficiency implying that farmers who had some formal education had an advantage in reading and writing which aids efficiency in farm production unlike those with no formal education. This is in contrast with the findings of Ndubueze-Ogaraku et al. (2021) who reported that education had a significant and positive effect on technical inefficiency. It was attributed to the fact that acquiring higher education could decrease farmers' concentration on the yam farming business thereby leading to technical inefficiency. Household size positively influenced the technical inefficiency of yam production implying that farmers with more household size were technically inefficient. This could be because most of the proceeds from the yam farming business were used to cater to the needs of the large family leading to technical inefficiency. Adoption was found to negatively affect technical inefficiency among yam producers. This indicated that farmers who adopted the YMT were more technically efficient than the non-adopters highlighting the benefits of the technology. This corroborates the findings of Asante et al. (2014) who reported that adoption of YMT significantly and positively influenced the technical efficiency of yam producers. The coefficient of extension contact is negatively related to technical inefficiency indicating that yam producers who had access to extension contact were more technically efficient than those who did not have this access. Access to extension support can lead to better productivity among farmers thus leading to technical efficiency. This aligns with the study conducted by Feder et al. (2010), which highlighted that agricultural extension agents play a vital part in transferring knowledge, skills, and technologies essential for enhancing farmers' production and income levels. They are recognized for their ability to facilitate and inspire farmers to adopt improved agricultural practices.

Table 2: Determinants of technical efficiency of yam producers

Output	Coefficient	Z	P>|z|
Herbicides	-0.040*	-1.85	0.065
Planting materials	0.796***	17.46	0.000
Labour cost	0.094**	2.12	0.034
Inefficiency model			
Gender (Male)	-0.040*	-1.77	0.080
Age	-0.478	-1.18	0.238
Educational level (Formal education)	-0.056**	-2.17	0.032
Land tenure	-0.118	-0.15	0.879
Household size	0.099**	2.03	0.045
Adoption (Yes)	-0.441*	-2.12	0.073
Farm experience	0.434	1.07	0.286
Extension contacts (Yes)	-0.081**	-1.72	0.088
Cooperative member (Yes)	-5.815	-0.80	0.422
Constant	68.010	0.02	0.983

***, **and *represents 1%,5%,10% levels of significance respectively

Impact of Yam Minisett Technology (YMT) Adoption on the Technical Efficiency of Yam Producers

Table 3 presents the technical efficiency scores for yam producers who have adopted yam minisett technology compared to those who haven't. The findings indicate a notable positive impact of yam minisett technology adoption on the technical efficiency of yam producers in the area.

All the adopters had individual technical efficiencies of 0.90 and above while a few of the non-adopters had individual technical efficiencies of less than 0.90. The minimum, mean and maximum efficiencies for adopters are 91%, 97%, and 99% respectively while the minimum, mean and maximum efficiencies for non-adopters are 65%, 96%, and 98% respectively indicating a difference in efficiency levels between adopters and non-adopters. These findings suggest that the adoption of yam minisett technology and adequate use of available resources are likely to increase efficiency by 1%. These findings are consistent with those of Asante et al. (2014), who found that the adoption of YMT was likely to increase technical efficiency in another region of Ghana. They however reported that the adoption of YMT was likely to reduce technical efficiency in Brong Ahafo region.

Table 3 Technical Efficiency Distribution of Adopters and Non-adopters of Yam Minisett Technology

	Adopters	Non-Adopters
Efficiency Level	Freq (percent)	Freq (percent)
≤ 0.90	0 (0)	3 (3.6)
> 0.90	77 (100)	40 (96.4)
Minimum Efficiency	0.91	0.65
Mean Efficiency	0.97	0.96
Maximum Efficiency	0.99	0.98

Influence of Adoption of Yam Minisett Technology on Farmers' Income.

Results presented in Table 4 show the influence of yam minisett technology adoption on farmers' income. Using the propensity score matching approach of the treatment-effect model, the study considered problems that could be associated with selection biases and particularly non-compliance or problems of endogeneity and used the endogenous treatment-effects model to assess the effect. The Average Treatment Effect (ATE) on the sub-population was N551,260.5. This implies that the respondents had about N 551,260.5 (USD 346) increase in their income after the adoption of YMT. This could translate to a significant impact of the adoption of YMT on the income of the respondents. This study is in line with findings associated with Nwike and Ugwumba (2016) who reported that the production of seed yam using the minisett technology is a profitable enterprise.

Table 4. Endogenous treatment-effects estimation

Variables	Coefficient	Std. Err.	z	P>|z|
ATE				
1 vs 0	551260.5***	133806.9	4.12	0.000

***, ** and * represents 1%, 5%, 10% levels of significance respectively

CONCLUSION AND RECOMMENDATIONS

The study highlighted factors such as gender, educational level, household size, adoption, and extension contact as significant predictors of technical efficiency albeit negatively or positively. The study found that while adopters and non-adopters of yam minisett technology had average technical efficiencies of 97% and 96% respectively, non-adopters displayed lower levels of individual technical efficiency at the minimum. Consequently, it was determined that utilizing yam minisett technology significantly impacts the technical efficiency and revenue of yam producers. Following these results, a set of recommendations was proposed.

i). The adoption of the yam minisett technology should be encouraged among farmers in Nigeria because of its potential to enhance their technical efficiency and income levels.

ii). Adequate planting materials should be made available to encourage and ensure the adoption of this innovation.

iii). The adoption of yam minisett technology and other such innovations should be closely monitored by a working extension training system to guarantee continuous use.

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