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EFFECT OF PURDUE IMPROVED CROP STORAGE TECHNOLOGY USE ON FARMERS' INCOME IN BENUE STATE, NIGERIA

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Abstract
Postharvest loss is a major contributing factor to food and income insecurity in Nigeria. Insects' damage on cowpea reduces quantity and quality of grains with significant effect on domestic consumption and market value. Use of innovative storage such as Purdue Improved Crop Storage (PICS) technology can help improve storability and reduce the economic losses in stored cowpea. However, there is limited empirical information on the welfare effect of PICS technology use. This study therefore investigates the effect of PICS technology use on farmers' income in Benue State, Nigeria. Data collected from 120 cowpea farmers and their corresponding counterfactuals in 12 communities of Benue state were used for the study. Descriptive statistics, propensity score matching and likert scale rating were used to analyse the data. The result reveal that majority of the respondents were male and married with a mean age of over 50 years. The mean level of formal education, and mean amount of credit accessed were 11.85 and 33,727.00 for the users and 8.97 and 22,575.00 for the non-users respectively. The result of the propensity score matching shows that use of PICS technology significantly improves the income per adult equivalent of the users, with the annual income for the treated higher than the population average. Damage by rodents, high cost, and scarcity of PICS bags are the significant constraints farmers' faces in use of PICS in the study area. It is recommended that rural development policies should encourage uptake by sensitizing farmers on the benefit of PICS use, while also providing regular support such as subsidy and credit access as well as enabling environment to ease scarcity and ensure regular supply of PICS technology.
Keywords: Cowpea, Losses, Income, Purdue, Storage, Technology, Nigeria

Introduction

Cowpea (*Vigna unguiculata*) is an important food legume crop in Nigeria. The seed is a valuable source of cash, nutrients and livelihoods for small-scale producers (Bolarinwa, 2022). Cowpea occupies a significant place in rain fed agriculture, providing food and fodder for livestock production in subsistence agriculture (Osipitan *et al.* 2021). It also enhances soil fertility through leaf drop and biological nitrogen fixation in soil. Cowpea is well adapted to all soil types and can be used as a cover crop for erosion control (Nwagboso, *et al.* 2024). Cowpea seed is highly nutritious and a great taste addition to any diet. It complements or substitute less-protein cereals and root-based diets. Owing to the unique characteristics and benefits in diets as well as the farming systems of poor, cowpea has become an ideal crop for reducing poverty and hunger, improving human health and nutrition, as well as enhancing ecological resilience (Razgonova *et al.* 2022).

However, despite these agronomical potentials and contribution to food security in Nigeria, storage loss remains one of the most problematic issues in cowpea postharvest management. Damage by weevil reduces quantity and quality of cowpea both for domestic consumption and market sales. Studies have shown that every insect emergence holes present in 100 seeds reduces the value of grains by 2.3% (Jones *et al*. 2018). In cases where the cotyledons or embryos are destroyed, the seeds can no longer be used for planting. This indicates that storage losses will drastically undermine production, household food and nutritional security (Singh *et al.* 2022) and by extension, income and socio-economic status of farmers.

Minimizing grain losses in the supply chain and maintaining grain quality could be a resource-efficient way to strengthen food security, sustainably combating hunger and improving farmers' livelihoods. However, most conventional method of storage cannot guarantee protection against these storage insects (Baributsa *et al.* 2020). Thus, Purdue Improved Cowpea Storage (PICS) bags provide opportunities to address postharvest losses among smallholder farmers. The technology plays an important role in reducing storage losses, through the lethal effect of low O2 /high CO2 atmosphere produced from the natural respiration processes in sufficiently sealed structures (Osei *et al.* 2022). The impermeability of containers alter the ambient environment where pests otherwise would thrive.

The technology has been gaining popularity among smallholder farmers in sub-Saharan Africa (SSA), Asia and Latin America as an improved method of grain storage (Odjo *et al.* 2020). However, despite the effectiveness in controlling storage pests, the effect of PICS technology usage on farmers' income has not been properly investigated. To address the issue raised; this study examines the effect of PICS technology use on the income of cowpea farmers in Benue State, while also identifying constraints in the use of PICS technology in the study area. Understanding this will help stimulate a shift from the traditional storage method and provide incentive to other actors along the food chain that will encourage greater uptake.

Research Methodology

The Study Area

The study was carried out in Benue State, Nigeria.

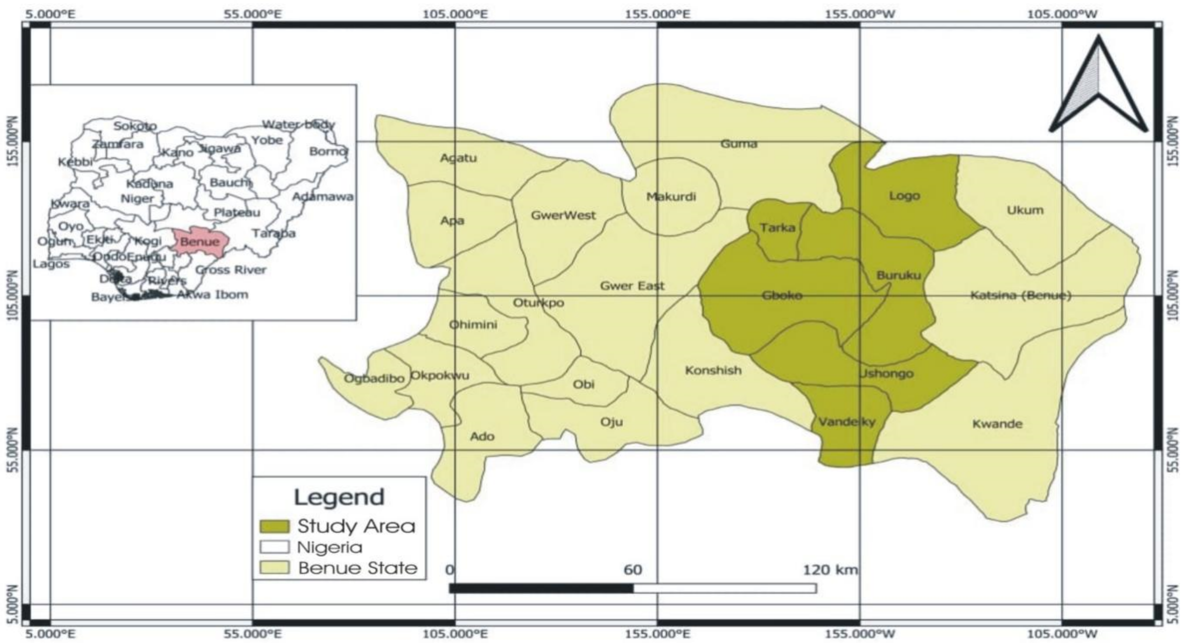

Fig 1. Map of Benue State, Nigeria

The state is located in North Central geopolitical zone of Nigeria. It cover a land area of about 33,955 sq km between longitudes 7° 47' and 10° 0' E and between latitudes 6° 25' and 8° 8' N. The state climatic cover is tropical and comprises two major seasons: the dry and the raining season. The wet season falls between April-October of each year while dry season runs between November to March of the next. The annual rainfall ranges from 1000-1500mm, while maximum average temperature ranges between 30^0C and 35^0C. The natural vegetation consists broadly of rain forest and wooded savannah (Benue State Agricultural Development Authority, 2021). According to the National Population Commission (NPC, 2019), the state has a population of 5,787,706 people with an average population density of 99 persons per km^2 and 413,159 farm families. The state is made up of twenty three Local Government Areas (LGAs) which is politically and agriculturally divided into three zones: Northern (zone A), Eastern zones (zone B) and Central (zone C) (Odoh *et al.*, 2020).

The main source of livelihood of the people is agriculture, hence the state is nicknamed – the Food Basket of the Nation. This is due to the fact that the state is endowed with rich fertile land and favourable climatic conditions suitable for agricultural production. The state are noted for the farming of crops including maize, millet, rice, sorghum, ginger, cowpea, groundnut, cassava and yam which are either in the monocropping or intercropping systems (Kughur *et al*, 2017). Cowpea is one of the dominant crops, accounting for about 25% of the total cultivated lands and grown mostly as intercrops with maize and other cereals.

Sampling Procedure and Data Collection

The study used primary data collected through a two-stage sampling procedure. First stage involved purposive selection of six major cowpea-producing communities' in two of the three agricultural zones in the State, namely :- Asukunya, Mbakor, Ugbema, Abwa, Vende, Mbadeda, Lessel, from agricultural zone A (North zone) and Ge-Mbagwa, Tse-Jiir, Abeda, Ihugh and Mbaakon from agricultural zone B (East zone). Because there is no available frame, snowball-sampling techniques was used to identify PICS users from the selected communities. This formed the sampling frame, where ten (10) users of PICS technology were selected at random from each of the 12 identified villages. In addition, 10 non-users (i.e. polypropylene/woven bags users) was also randomly selected from the villages to act as control, thus making a total sample size of two hundred and forty (240) respondents interviewed for the study.

Data Analysis

Descriptive Analysis

Descriptive statistics such as frequency tables; mean, percentages and standard deviation were used to present the socio-economic characteristics.

Outcome estimation

The outcome (income) was measured using the Organization for Economic Co-operation and Development (OECD) scales of equivalence. The OECD scales was used in order to capture differences in farm households' composition and is estimated as the ratio of total annual household income and household's equivalence scale defined as:

$$N' = 1 + 0.5.(N_{adults} - 1) + 0.3.N_{children} \quad (1)$$

Where:

N' – equivalised household size,

N_{adults} – the number of adults and

$N_{children}$ – the number of children in household

Within each household, the first adult counts 1, all children under 14 get a weight of 0.3 and any additional person aged 14 and above gets a weight of 0.5. The obtained value was expressed in annual per adult equivalent (AE) basis, given as:

$$IE_i = {}^{A_{hi}}/_{N'},$$

where, $A_{hi} = FI + NFI \quad (2)$

Therefore, $IE =$ annual income per adult equivalent, $A_{hi} =$ total annual household income, $FI =$ annual farm income, NFI = non-farm income per annum.

Propensity score matching (PSM)

When a treatment cannot be randomized, the next best thing is to mimic randomization by selecting a group of non-beneficiaries that resemble the beneficiaries in everything. If such resemblance is satisfactory, the outcome observed for the matched group approximates the counterfactual, and the effect of the intervention can be estimated as the difference between the average outcomes of the two groups.

Thus, propensity score matching defined as the conditional probability of receiving a treatment based on observed characteristics X (Rosenbaum & Rubin 1983), was employed to determine effect of the usage of PICS technology on farmers' income. The propensity scores computed using binary probit regression models given as:

$$P(X)Pr\{D=1/X\}=E\{D/X\} \quad (3)$$

D= {0, 1} is the indicator of exposure to treatment characteristics. That is, D=1, if exposed to treatment and D=0 if not exposed to treatment. X is the multidimensional vector (explanatory variables such as farmer specific, technology and market variables) which are expected to jointly determine the probability of the outcome Q.

Thus,

$Q=\gamma X+\delta D+\mu$ (4)

Where, Q represents the outcome variable, D is an indicator variable for adoption of PICS,

γ and δ are vector of parameters to be estimated, and μ is an error term.

The model is specified as follows:

Q = Annual income per adult equivalent (₦); X_1= Gender of the household head (male=1, 0 otherwise); X_2= Age of the household head (years); X_3= Marital status of the household head (married=1, 0 otherwise); X_4= Household size (numbers); X_5= Farmers level of education (years); X_6 = Amount of credit (₦); X_{12} = Price of cowpea (₦); X_{13} = Weight loss in stored grain (*kg*); X_{14} = Cost of storage structure (₦); X_{15} = Quantity of cowpea stored (kg);

X_{16} = Duration of storage (months).

The Average Treatment Effect for the Treated (ATT) estimated as the average difference between the income of the farming households who use the hermetic storage and farmers who do not use the hermetic storage, using;

ATT=

$$E(Q^1-Q^0/D=1)=E(Q^1/X,D=1)-E(Q^0/X, \quad (5)$$

Where,

$E(Q^1/D=1)$ the observed outcome of the treated, that is, the expected outcome (income per adult equivalent) of PICS users, and $E(Q^0/D=1)$ is the counterfactual outcome - the expected outcome they would have received if farmers had not used PICS hermetic storage bag.

Kernel matching which uses weighted averages of all individuals in the control group to construct the counterfactual outcome was used. The approach ensures lower variance is achieved as more information is used. The matching estimator is given as:

$$\tau^k=\frac{1}{N^T}\sum_{i\epsilon T}\left\{Q_i^T-\frac{\sum_{j\epsilon c}Q_j^c G\left(\frac{P_j-P_i}{h_n}\right)}{\sum_{k\epsilon c}G\left(\frac{P_k-P_i}{h_n}\right)}\right\} \quad (6)$$

Where, G(.) is a kernel function and h_n is a bandwidth parameter. Under standard conditions on the bandwidth and kernel, $\frac{\sum_{j\epsilon c}Q_j^c G\left(\frac{P_j-P_i}{h_n}\right)}{\sum_{K\epsilon c}G\left(\frac{P_k-P_i}{h_n}\right)}$ is a consistent estimator of the counterfactual outcome Q^0.

The advantage of using a weighted average as opposed to the nearest neighbour method is that it improves the efficiency of the estimator. All observations whose propensity score is smaller than the minimum and larger than the maximum in the opposite group were dropped from the analysis.

Likert Type Scale

A five-point Likert scale were used to present the farmer response to the identified constraints in the use of PICS storage technology in the study area. The farmers response were grouped into: strongly agree=5, agree=4, neutral =3, disagree=2, strongly disagree=1;

The responses are represented as;

5+4+3+2+1 = 15/5 =3.0

Therefore, a mean of three and above are accepted and adjudged significant factor constraining the use of PICS, while any value below three, shows non-constraint in the use of PICS.

Results and Discussions

Socio-economic Attributes of the Respondents

The summary statistics (Table 1**)** shows that, majority of the respondents across the two groups are male, while the female constitutes about 27% for the users and 35% for the non-users respectively. Most of the respondents, (31.7%) users and (50%) non-users of PICS technology were within the ages of 51-60 years, with a mean age of 51 and 55 years for the users and non-users respectively. Married respondents constituted 75.8% for the users and 67.5% for the non-users of PICS technology. Majority of the respondents, for both categories have average household size of six persons.

Table 1: Descriptive Statistics of Users and Non-Users of Pics Technology

Variables	Users Frequency	Percentage	Non-Users Frequency	Percentage
Gender				
Male	88	73.3	78	65.0
Female	32	26.7	42	35.0
Age (in years)				
≤ 30	2	1.7	1	0.8
31-40	18	15.0	6	5.0
41-50	36	30.0	30	25.0
51-60	38	31.7	60	50.0
> 60	26	21.6	23	19.2
	M= 51.66		M=55.73	
	SD= 0.284		SD= 0.412	
Marital status				
Single	10	8.3	4	3.3
Married	91	75.8	81	67.5
Divorced	5	4.2	7	5.8
Widowed	14	11.7	28	23.3
Household Size				
≤ 3	11	9.2	1	0.8
4-7	71	59.2	89	74.2
8-11	35	29.2	28	23.3
> 11	3	2.4	2	1.7
	Mean=6.48		Mean=6.61	
	SD= 0.190		SD= 0.311	
Level of Education				
No formal	18	14.9	22	18.2
Primary	37	30.6	54	44.6
Secondary	53	43.8	35	28.9
Tertiary	12	9.9	9	7.4
	Mean= 11.85		Mean= 8.97	
	SD=0.376		SD=0.354	
Farming Experience (Years)				
≤ 10	18	15.0	6	5.0
11-20	62	51.6	67	55.8
21-30	35	29.2	46	38.4
>30	5	4.2	1	0.8
	M=18.76		M=19.67	
	SD= 0.267		SD= 0.492	

Source: Field survey, 2020

The result also showed that majority of the respondents had formal education, with the mean level of formal schooling of 11.85 and 8.97 for the users and non-users respectively. This indicated that most of the users completed some secondary education while majority of the non-users had primary education. Greater proportion of the respondents have about 11 - 20 years farming experience, with average farming experience of 18 years and 19 years for the users and non-users respectively.

Summary of Selected Economic Attributes of the Respondents

The result from table 2 showed that majority of the respondents from both category earn between ₦100,001 to ₦300,000 farm income annually. The mean farm income was ₦186,300 for the users and ₦167,116 for the non-users. Similarly, most of the respondents earn off-farm income of between ₦300,000 and below, annually.

Table 2: Summary statistics of selected economic variables of the respondents

Variables	Users Frequency	Percentage	Non-Users Frequency	Percentage
Annual Farm Income (₦)				
≤ 100,000	20	16.7	29	24.2
100,001-300,000	92	76.7	87	72.5
300,001-500,000	6	5.0	3	2.5
> 500,000	2	1.6	1	0.8
	Mean= 186,300 SD = 31.610		Mean= 167,116 SD = 26.174	
Off farm income (₦)				
≤ 100,000	53	60.0	34	51.5
100,001-300,000	44	42.3	30	45.5
300,001-500,000	5	4.8	2	3.0
> 500,000	2	1.9	0	0
	Mean= 138,730*** SD = 21.332		Mean= 112,924 SD = 14.191	
Amount of credit (₦)				
≤ 20,000	30	54.5	20	60.6
20,001-45,000	18	27.3	12	36.4
45,001-70,000	11	16.7	1	3.0
> 70,000	7	10.5	0	0
	Mean= 33,727** SD= 8.771		Mean= 22,575 SD= 5.530	
Quantity stored (per 100 Kg bag)				
≤ 1	2	1.7	33	27.5
1.01-2	21	17.5	70	58.3
2.01-3	42	35.0	13	10.8
> 3	55	45.8	4	3.3
	Mean= 3.17*** SD = 0.745		Mean= 1.64 SD = 0.623	

Source: Field survey, 2020 Significant @ 5% level

The average off-farm income for the users was ₦138,730 while the non-users average was ₦112,924. The results showed that, most of the respondents' access credit amount of ₦20,000 and below, with average amount of ₦33,727.00 and ₦22,575.00 accessed by each group of respondents. In addition, greater proportion of the users stored above 200 kg of cowpea, while most non-users store 200 kg and below, with an average storage size of 317 kg and 164 kg each.

Effects of PICS Technology Usage on Income of farmers

Table 3 presents the average treatment effect on the treated (ATT) and the population average treatment effect (ATE). The estimated impact parameters of the propensity score shows that the average treatment effect on the treated (ATT), which measure the effect of PICS technology on the users, was ₦15,252.83, with a score of 4.66 and 1% level of significance.

Table 3: Estimated Impact Parameters for Propensity Score Matching

Variable	Sample	Coef	AI Robust. Std. Err.	z	P>|z	[95% Conf. Interval]	
Income per equivalent	ATT	15252.83	3275.359	4.66	0.000	8833.24	21672.41
	ATE	11343.82	2248.226	3.07	0.002	5778.51	16909.12

Source: Field survey, 2020

While the population average treatment effect (ATE) shows that, when picked at random, the respondents' income per equivalent would be ₦11, 343.82. This indicates that the users annual income per adult equivalent increase by ₦3, 909.01 than the population average. Since the ATT is greater than ATE, it therefore implies that, PICS technology has a significant impact on the income of PICS technology users. Thus shows a better economic effect for PICS users than those storing with polypropylene bags in the study area.

Constraints in the use of PICS Technology

This section present the summary of farmers' response score to identified challenges in the use of PICS technology in the study area (Table 4), **(n=120)**

Table 4: Likert Scale Estimation on Constraints to PICS Technology Use

Constraints	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean score	Decision
Leakage	16	19	24	38	23	2.73	Rejected
High cost of PICS	25	24	23	26	22	3.03	Accepted
Rat/rodent attack	24	38	31	17	10	3.40	Accepted
Termite attack	8	20	35	34	23	2.63	Rejected
Scarcity of PICS bag	27	27	29	18	19	3.20	Accepted

Source: Field survey, 2020

Table 4 captured the opinions of the respondents based on weighted mean in line with the 5-point Likert scaling. Three variables were accepted and two others rejected as constraints to PICS technology use.

From the result, rodents' damage on the bags had the highest mean score and constituted the greatest constraint to PICS technology use in the study area. In addition, scarcity of PICS bags and high cost of PICS bag also score point higher than 3.0, indicating that they are prominent factor constraining the use of PICS technology. On the other hand, leakage and termite attacks on the bag scored points lower than three, which means that the variables were seemingly not significant factor limiting the use of PICS bags in the study area.

Conclusion

The need for better storage management to sustainably combating hunger and improve farmers' livelihoods is an important development concern in agriculture. This study contribute to literature by examining the effect of PICS technology use on farmers' income, while also isolating constraints in the use of PICS technology. The study confirms that male and married respondents have more access to PICS technology than their female counterpart does. The propensity Score matching result also revealed that storing with PICS technology improves income of the users, with the annual income significantly higher than the non-users. Damage by rodents, high cost, and scarcity of PICS bags are the major constraining factors affecting the use of PICS in the study area. The use of PICS technology will facilitate sustainable improvement in income and food security among farmers if these constraints are addressed. The study therefore recommended that rural development policies should encourage uptake by sensitizing farmers on the benefit of PICS use, while also providing regular support such as subsidy and credit access as well as enabling environment to ease scarcity and ensure regular supply of PICS technology.

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