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A Study on the Adoption and Impact of Finger Millet Landrace (Bada Mandia) in Koraput District of Odisha

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ABSTRACT

The present study has analysed the adoption and impact of finger millet landrace, *'Bada Mandia'* on yields and net income of smallholders in Koraput district of Odisha using the Propensity Score Matching (PSM) technique. To validate the PSM findings, doubly robust models, viz., Inverse Probability Weighted Regression Adjustment (IPWRA) and Augmented Inverse Propensity Weighted (AIPW) estimator were used. A stratified purposive sampling technique was employed to select a representative sample of 100 treated and 250 untreated farmers. The findings from Propensity Score Matching revealed that the mean yield and net income among treated farms are significantly higher than the non-adopter counterparts across different matching algorithms. The results from IPWRA and AIPW also showed a positive and significant impact on the adoption of *Bada Mandia* on finger millet yield and net income of treated farms. The results further pave the way for future policymaking for increased production and income for the farmers at large from finger millet cultivation in the State.

Keywords: Finger millet, Propensity Score Matching (PSM), Average Treatment Effect (ATE), Adoption Index, Foster- Greer–Thorbecke (FGT Model), Doubly Robust Models

JEL: Q01, Q13, Q16

I

INTRODUCTION

In light of the challenges posed by climate change and the increasing demands due to population rise, crop diversification has gained due attention. As a result, there has been a resurgence in the cultivation of millet crops. Finger millet in particular has proven to perform well in adverse agro-climatic conditions and has significant nutritional value compared to other cereals. So, improving the productivity of finger millet is seen as a potential solution to reduce poverty, malnutrition, and hunger**.**

In response to these challenges, efforts have been made to revitalise finger millet production in India. Finger millet (*Eleusine coracana*), grown in arid and semi-arid regions is known for its resilient nature, making it a suitable crop in these areas.

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Research organisations and government agencies are working to develop improved finger millet varieties with higher yields, improved nutritional content, and resistance to pests and diseases. These efforts aim to enhance the productivity and profitability of finger millet farming (Gupta *et al*., 2017**).** Awareness campaigns and capacity-building programmes are also being conducted to promote the cultivation and consumption of finger millet. Overall, the revitalisation of finger millet in India is part of a broader strategy to alleviate poverty and food insecurity.

The Government of Odisha launched the Odisha Millets Mission (OMM) in tribal areas that focuses on reviving millet cultivation in farms. It includes developing and disseminating improved finger millet varieties, training programmes for farmers, capacity building, and market linkages to ensure better returns for the farmers. The area covered under Odisha Millet Mission (OMM) was 0.55 lakh hectares during the 2021-22 period of which finger millet dominated, occupying over 83.68 per cent of the total cultivated area**.** As a result, the total area under finger millet increased from 115.79 thousand ha in 2018-19 to 120.425 thousand ha in 2020-21 in the State of Odisha **(**Government of Odisha,2021; 2022). Recently, as a landmark achievement, Odisha has become the first State in the country to formally release four Millet Landraces as varieties. The landraces/farmer varieties are Kundra Bati, Laxmipur Kalia, Malyabanta Mami and Gupteswar Bharati. Although they have better tolerance to pest and climate changes, they are confined to limited areas of Koraput and Malkangiri districts.

Koraput district is the largest producer of finger millet at the national as well as state levels. In Koraput, the area under finger millet covers approximately 0.74 lakh hectares of cultivated area, accounting for about 24.7 per cent of the total cultivated area in the district during 2021-22. The predominant finger millet varieties cultivated by the farmers in Koraput include *Bada Mandia* (0.11 lakh ha) followed by *Bhairabi* (0.07 lakh ha), *Sana Mandia* (0.03 lakh ha), *Badi Mandia* (0.02 lakh ha), *Bati* (0.008 lakh ha), *Arjuna* (0.006 lakh ha) (Source: District Agriculture Office, Koraput and WASSAN)**.** These landraces have remarkable adaptability to the local condition along with robust resistance to pest and changing climates. It makes them particularly well suited for organic agricultural practices. *Bada Mandia* is the predominant landrace cultivated by the small and marginal farmers of the area. The selection of *Bada Mandia* is primarily driven by its promising average yield of 12.5 quintals per hectare, along with desirable traits such as non-lodging and good taste. This landrace is also adopted by a maximum number of farmers and researchers for participatory varietal trials *Bada Mandia* is also known for its nutritional composition, rich in protein, fibre, antioxidants, flavonoids, and various other nutrients, making it suitable for both food security and improved dietary diversity in the region. Bada Mandia is identified to have increased nutrient superiority over other finger millet genotypes and may be considered a reliable source of security for the local tribals. The identified genotype has abundant quantities of nutritional and nutraceutical composition that can be used as a non-conventional food to supplement the diet

(Panda *et al.*, 2022). The cultivation of the *Bada Mandia* landrace has brought major economic benefits to the farmers in the Koraput district.

With this background, the current study has been undertaken with the following specific objectives: (i) To study the extent of adoption of Bada Mandia cultivar vis-à-vis other cultivars available in the locality and (ii) To analyse the impact of Bada Mandia cultivar on net income of smallholder farmers.

II

DATA AND METHODS

Stratified purposive sampling was adopted for the selection of study area as per the highest acreage of finger millet in the location. Koraput district was selected purposively based on the area under finger millet production. Three blocks, viz., Dasmantpur, Lamtaput and Boipariguda, and one village from each block (i.e., Batisili, Tukum and Mathpada respectively) were subsequently selected purposively for the study having the highest acreage under finger millet. Two sampling frames were considered comprising the list of farmers who cultivated high-yielding finger millet varieties, *Bada Mandia* (treated) vis-à-vis farmers who cultivated other varieties (untreated) during *kharif*. Farmers were selected based on a simple random sampling technique from the above two categories. Finally, a representative sample of farmers was selected who adopted high-yielding finger millet varieties during *kharif* 2022 (treated) (n=100) and the farmers who cultivated other varieties during the same season are considered as untreated (n=250) categories. One of the key principles in propensity score matching is to balance the covariates (pre-treatment characteristics) between the treated and untreated groups. One way to address the issue of covariate balance is by ensuring that the untreated sample size is adequate. This can be achieved through a selection process that is often based on the probability proportion to size, which means that the size of the untreated group is determined based on the prevalence of the treatment in the population. A larger untreated sample size allows for a better chance of finding suitable matches for each treated individual, improving the overall balance in terms of observed covariates. A structured schedule was used to collect the requisite data (Table 1).

TABLE 1. TYPES AND DEFINITIONS OF VARIABLES

Variable type (1)	Abbreviation (2)	Variable definition (3)
Treatment variable	Treat	Adoption of Bada Mandia/Dummy(1=Yes, 0 =No)
Covariates	REF	Research- Extension- Farmer linkages/ Dummy (1=Yes, 0 =No)
	LHS	Landholding size (ha)
	EDU	Education of the farmer (years)
	GAP	Adoption of Good Agricultural Practices (GAP)/Dummy (1=Yes, 0=No)
	FE	Years of Farming Experience
	AMI	Access to market information/Dummy(1=Yes, 0 = No)
Outcome Variables	FMY	Finger millet yield (Quintals/ha)
	FMNI	Net income from cultivation of finger millet (Rs/ha)

(i) *Analytical Tools*

*a. Descriptive Statistics***:** To analyse the socio-economic characteristics between treated and untreated farmers, Mean and Standard Deviation (SD) were exercised.

*b. Adoption index***:** The adoption index (β_Y) was calculated for both treated and untreated farmers using the methodology proposed by Philips *et al.* (2000).

$$\beta_Y = \sum_{i=1}^{n} R_i / \sum_{i=1}^{n} R_T \qquad \text{…. (1)}$$

where β_Y: Adoption rate for Bada Mandia,
R_i: Land area has grown under Bada Mandia by the ith farmer,
R_T: Total land area by the ith farmer and i = (1,2,3 …. n farmers).

$$PPI = (\Delta Y / \overline{Y})\ (\beta_Y) \qquad \text{…. (2)}$$

where, PPI = Proportional production increase,

ΔY= change in yield (i.e., mean yield of Bada Mandia– mean yield of other landraces),

$\overline{Y}$= mean yield in the area regardless of landraces, and

β_Y= adoption index of Bada Mandia

c. Estimation of Poverty Profile (Foster- Greer–Thorbecke (FGT) Model): The FGT model (Foster *et al*., 1984) provides measures of poverty incidence, depth, and severity and *is represented below:*

$$P_{(\alpha)} = (1/n)\sum_{i=}^{q}\{(y_p - y_i)/y_p\}^{\alpha} \qquad \text{.... (3)}$$

where ‘n’ is the number of sample households, ‘y_i’ is the income of the ith household, and ‘y_p’ represents the poverty line indicated by the income limit for households qualifying as a beneficiary under the Below Poverty Line (BPL) (ie., a person with annual family income not exceeding Rs.40,000/- in a rural area (Department of Health & Family Welfare, Government of Odisha), ‘*q’* isa number of households BPL, and ‘α’ is the poverty parameter (incidence, gap, and severity) that take the values of 0, 1 and 2.

d. PSM Technique: PSM was employed to study the impact of the adoption of Bada Mandia on yield and net income. Matching algorithms such as Nearest Neighbour Matching (NNM), Kernel-Based Matching (KBM), Radius Matching (RM), and Stratified Matching (SM) were used (Akhter and Olaf, 2017). The PSM can be expressed as:

$$p(X) = \Pr\,[D = 1|X] = E[D|X];\ p(X) = F\{h(X_i)\}, \qquad \text{…. (4)}$$

where p(X) is a propensity score and Pr is the probability of adopting Bada Mandia (treated farmer will receive the value of ‘1’, and ‘0’ otherwise).

e. Doubly Robust Models – IPWRA and AIPW: To validate the PSM findings, Average Treatment Effect (ATE) using the IPWRA and AIPW models was estimated (Fasakin *et al.*, 2022). To eliminate the problem of biased estimates, IPWRA and AIPW models were used (Wooldridge, 2007). The ATE for the IPWRA can be specified as:

$$ATE_{IPWRA} = N^{-1}\sum_{i=1}^{N}[(\alpha_1^* + \beta_1^* X_i) - (\alpha_0^* + \beta_0^* X_i)]$$

$$= [(\alpha_1^* - \alpha_0^*) + \overline{X_1}(\beta_1^* - \beta_0^*)]$$

where (α_1^*, β_1^*) are attained from the inverse probability-weighted least squares problem for the treated group

$$min_{\alpha_1\beta_1} \sum_{i=1}^{N} \frac{(y_i - \alpha_1^* - \beta_1^* X_1)^2}{\hat{p}(X, \hat{\gamma})}$$

and (α_0^*, β_0^*) are attained from the inverse probability-weighted least squares problem for untreated group

$$min_{\alpha_0\beta_0} \sum_{i=0}^{N} \frac{(y_i - \alpha_0^* - \beta_0^* X_0)^2}{1 - \hat{p}(X, \hat{\gamma})}$$

The * on the estimated parameters α, β, and X describes the double robustness result; $\hat{p}(X, \hat{\gamma})$are the estimated propensity scores.

The AIPW estimator is an inverse-probability weights estimator that includes an augmentation term that corrects the treatment model when it is mis-specified (Laan and Rubin, 2006). The “double robustness” property of AIPW and IPWRA means that only the treatment model or the outcome model needs to be correctly specified for the estimation to be consistent. Even the mis-specification of PSM can still lead to biased ATE and Average Treatment Effect on the Treated (ATET). In view of this, employment of IPWRA and AIPW estimators is justified against such a predicament, as they provide double robust consistent outcomes. Further, introducing these less-utilised approaches can bring fresh perspectives and insights to the field of impact evaluation in social sciences (Glynn and Quinn, 2010).

III

RESULTS AND DISCUSSION

(i) *Descriptive Statistics:* In Table 2, the results of the t-test show significant differences between the two groups in variables such as REF, LHS, GAP, FE, yield, and net Income.

TABLE 2: DESCRIPTIVE STATISTICS OF VARIABLES ACROSS TREATED VS UNTREATED

Variables (1)	Full Sample (n = 350)		Treated (n = 100)		Untreated (n = 250)		t-test (8)
	Mean (2)	SD (3)	Mean (4)	SD (5)	Mean (6)	SD (7)	
REF	0.71		0.891		0.242		3.92**
LHS (acres)	1.33	0.9877	1.451	0.852	1.269	1.018	3.84***
EDU (years)	8.22	8.764	8.298	8.3	8.181	8.474	0.15
GAP	0.76		0.835		0.603		5.08***
FE (Years)	28.25	11.294	30.155	11.809	27.279	10.913	2.52**
AMI	1.54		1.894		1.448		1.14
Yield (Kg/ha)	1308.26	271.9	1908.97	150.8	1158.09	149	29.62***
Net income (Rs/ha)	21945.25	3300	30347.58	1901	19139.62	1917	26.60***

Note: *** and ** denote significance levels at 1 and 5 per cent levels respectively.

(ii) *Adoption of Finger Millet Varieties:* Table 3 illustrates that the adoption index for *Bada Mandia* variety is the highest at 80.7 per cent.

TABLE 3: ADOPTION INDEX FOR MAJOR FINGER MILLET VARIETIES CULTIVATED (N = 350)

Variety (1)	Number of farmers (2)	Area under *Bada Mandia* (ha) (3)	Total Finger millet area (ha) (4)	Adoption index (5)	Average yield (kg/ha) (6)
Bada Mandia (Treated)	100	163.76	202.92	0.807	1908.97
Untreated					
Bhairabi	78	146.76	220.12	0.667	1501.14
Sana Mandia	71	109.4	167	0.655	1311.23
Badi Mandia	63	58.8	99.6	0.590	1016.79
Bati	38	40.28	55	0.732	803.19
Total	250	355.24	541.72	0.656	1158.09

(iii) *Estimation of Poverty Status Among Selected Farmers:* According to Figure 1, the depth (17.06 per cent) and severity indices (8.55 per cent) of poverty were observed to be higher among the untreated farmers compared to the treated farmers which are in alignment with the studies of Akinrinola and Adeyemo, 2018.

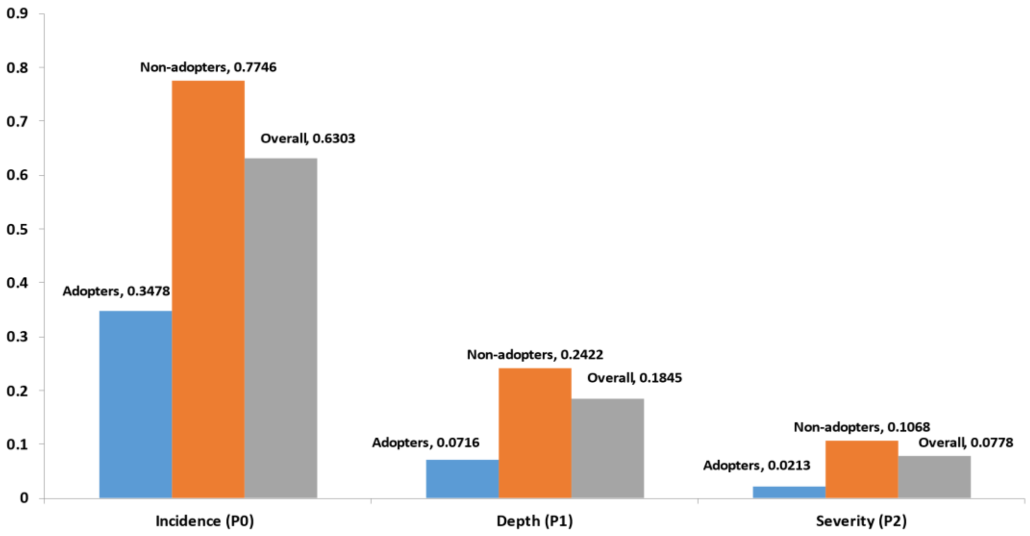

Figure1: Poverty incidence, depth and severity based on Bada Mandia technology adoption

iv. Impact of Adoption of Bada Mandia on Yield and Net Income

(a) PSM - Determinants of Farmers' Adoption of Bada Mandia: The results obtained from probit model, as presented in Table 4, revealed a positive and significant relationship between the selected variables and the adoption of *Bada Mandia* technology.

TABLE 4: PROBIT MODEL RESULTS OF DETERMINANTS OF FARMERS' ADOPTION OF *BADA MANDIA* TECHNOLOGY

Treat (1)	Coefficient (2)	Std. Err (3)	Z (4)	P>|Z| (5)
REF	0.084	0.020	4.17	0.000***
LHS	0.011	0.044	3.96	0.000***
EDU	0.255	0.067	3.79	0.000***
GAP	0.040	0.011	3.62	0.000***
FE	0.020	0.014	1.49	0.136
AMI	0.306	0.106	2.9	0.004***
Cons	0.510	0.437	1.17	0.243
Pseudo R^2	0.385			
LR chi-square (6)	51.792*** (Prob> chi2 = 0.000)			
Log likelihood	-278.678			

Note: *** indicate significant at 1 per cent probability level.

(b)Estimation of the Propensity Scores: By employing PSM, Common Support Condition (CSC) was derived and found satisfactory within the range of (0.0639 to 0.8439) and with a mean of 0.3486 (Table 5). So, farmers with estimated propensity scores falling within the aforementioned range were considered for the matching exercise. Consequently, 17 untreated farmers were excluded from this analysis.

TABLE 5: ESTIMATED PROPENSITY SCORES

(1)	Percentiles (2)	Smallest (3)	(4)	(5)
1%	0.080	0.064		
5%	0.116	0.070		
10%	0.147	0.072	Obs.	350
25%	0.244	0.079		
50%	0.345		Mean	0.349
		Largest	Std. Dev.	0.143
75%	0.448	0.654		
90%	0.542	0.660	Variance	0.020
95%	0.583	0.690	Skewness	0.110
99%	0.654	0.844	Kurtosis	2.470

(c) Matching quality/effect estimation: From Table 6, it is found that after matching, the t_{cal} values turned insignificant indicating that all covariates were effectively balanced in the model.

TABLE 6: TESTING OF COVARIATES BALANCE FOR TREATED AND UNTREATED

Variable (1)	Unmatched/ Matched (2)	Mean Adopter (3)	Mean Non-adopter (4)	Per cent SE bias (5)	Per cent SB reduction in bias (6)	t test t_{cal} (7)	t test P>|t| (8)
p-score	Unmatched	0.403	0.304	70.1		7.07	0.000
	Matched	0.398	0.398	0.1	99.9	0.01	0.994
REF	Unmatched	0.519	51.905	0.2		0.02	0.981
	Matched	0.518	51.094	6.3	-2610.6	0.55	0.582
LHS	Unmatched	3.627	3.175	48.2		4.84***	0.000
	Matched	3.591	3.598	-0.7	98.6	-0.07	0.946
EDU	Unmatched	4.298	4.181	2.4		0.25	0.800
	Matched	4.352	4.623	-5.5	-130.8	-0.48	0.631
GAP	Unmatched	0.602	0.835	-35.2		-3.40***	0.001
	Matched	0.610	0.579	4.8	86.5	0.49	0.623
FE	Unmatched	30.155	27.279	25.3		2.64 ***	0.008
	Matched	30.006	29.063	8.3	67.2	0.74	0.462
AMI	Unmatched	1.894	1.848	6.8		0.68	0.498
	Matched	1.893	1.837	8.2	-21.0	0.76	0.447

Note: *** indicates P≤0.01

(d) Estimation of ATE: The analytical findings presented in Tables 7 and 8 revealed a significant and positive impact of *Bada Mandia*adoption on yield and net income respectively (Adeyemi *et al*., 2020). The findings also illustrate the ATE results for treated farmers' yield and net income were also positive and significant.

TABLE 7: ESTIMATION OF ATE FOR FINGER MILLET YIELD OF SMALLHOLDER FINGER MILLET FARMERS

(*kg/ha*)

ATE estimator	ATE	Standard Error	t-value	Treated	Untreated
NNM	762.31	53.56	14.23***	100	232
RM	760.15	38.27	14.19***	99	241
KBM	757.84	38.37	14.15***	100	241
SM	761.28	39.61	14.21***	99	244

Note: *** indicates P≤0.01

TABLE 8 ESTIMATION OF ATE FOR NET INCOME (RS/HA) OF SMALLHOLDER FINGER MILLET FARMERS

ATE estimator	ATE	Standard Error	t-value	Treated	Untreated
NNM	11342.04	490.35	23.13***	100	232
RM	11321.02	487.04	23.24***	99	241
KBM	11354.75	480.20	23.65***	100	241
SM	11357.34	493.86	23.00***	99	244

Note: *** indicates P≤0.01.

(e) Testing the Balance of Propensity Scores: The findings presented in Table 9 and Figure 2 showed low Pseudo-R^2 and insignificant likelihood ratio test and these provided evidence that both groups had similar distributions in the outcome variables following matching.

TABLE 9: PSM QUALITY INDICATORS

Indicators (1)	Before Matching (2)	After Matching (3)
Pseudo-R^2	0.088	0.005
LR chi2	53.451	2.061
P>chi2	0.000	0.956
Mean Absolute Bias	26.911	4.818
Med Bias	25.327	5.506

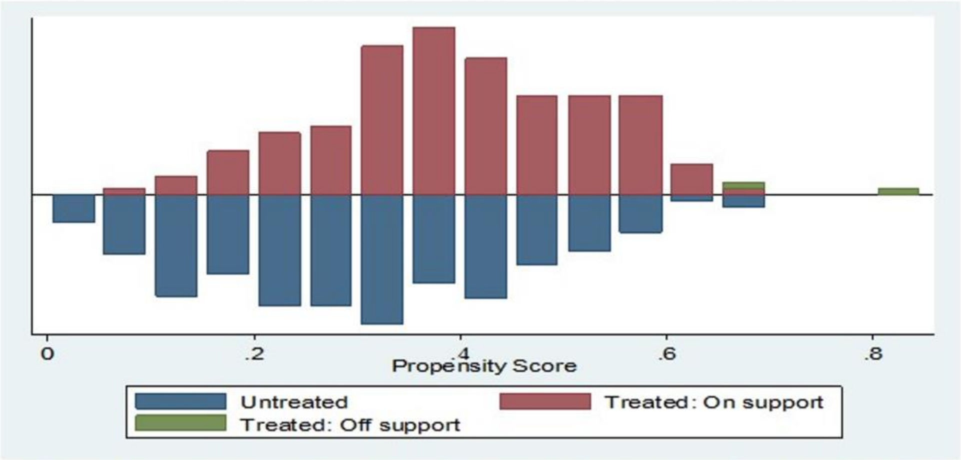

Figure 2: Propensity score distribution and common support. Treated: On support indicates adopters of Bada Mandia have a suitable comparison group (Untreated). Treated: Off-support indicates the adopters of Bada Mandia that did not have a suitable comparison group (Untreated)

v. Double Robust Estimation of Treatment Effects: To address the potential endogeneity problem, this study employed doubly robust models, namely IPWRA and AIPW estimators. Table 10 presents the ATE and ATET resulting from *Bada Mandia* adoption, as estimated by the aforementioned models. The ATE estimates, which represent the difference in means between the treatment and untreated groups, consistently demonstrated similar signs, magnitudes, and levels of significance. Consequently, the farmers' adoption of *Bada Mandia* had significant positive impact on both yields and net income among the treated farms, compared to untreated farms.

TABLE 10: ATE AND ATET EFFECTS ACROSS SELECTED MODELS AND OUTCOME VARIABLES

Model/ Outcome	IPWRA			AIPW	
	ATE	Per cent change over PO mean of Untreated	ATET	ATE	Per cent change over PO mean of Untreated
(1)	(2)	(3)	(4)	(5)	(6)
Logit model					
Yield (kg/ha)	760.79** (45.52)	67.28	753.81** (42.18)	758.52** (39.83)	66.85
Net income (Rs./ha)	11317.32** (503.98)	59.54	11291.37** (543.21)	11365.16** (507.20)	59.63
Probit model					
Yield (kg/ha)	759.82** (39.31)	66.44	748.49** (40.86)	754.92** (40.14)	65.45
Net income (Rs./ha)	11380.57** (514.74)	60.43	11301.26** (544.26)	11373.16** (531.22)	59.37
Heteroscedastic Probit model					
Yield (kg/ha)	757.33** (31.28)	66.20	745.21** (43.09)	751.74** (40.91)	65.23
Net income (Rs./ha)	11394.72** (30.37)	60.29	11336.34** (527.39)	11390.21** (541.68)	60.15

Note: Figures in parentheses indicate Robust Standard Errors.
** indicate 'Z' statistics significance at 1 per cent level.

This conclusion aligns with the previous studies conducted by Mottaleb *et al.* (2017); Dar *et al*. (2020) and Sadique *et al*. (2022). The ATET results from IPWRA indicate that if farmers in the untreated group were to adopt the *Bada Mandia* , there would be a potential increase in yield ranging from 745.21 kg/ha to 753.81 kg/ha, and an increase in net income ranging from Rs.11291.37/ha to Rs.11336.34/ha. This highlights the contribution of *Bada Mandia* in improving both yield and net income for treated farmers. Therefore, increasing the adoption of *Bada Mandia* among farmers would lead to higher yields and subsequently higher net income.

The findings of the selection model, as presented in Tables 11 and 12, indicate that GAP and AMI have a significant positive influence on the adoption of finger millet technology. Additionally, the probability of adopting *Bada Mandia* is biased towards farmers enjoying REF linkages and higher FE, as these factors prompt farmers to avail themselves of *Bada Mandia* in a timely manner and subsequently benefit from increased technical expertise and AMI for inputs and outputs.

The outcome equations for both untreated and treated categories also reveal significant influences of various variables. For untreated farms, factors such as LHS

TABLE 11. PREDICTED PROBABILITY OF *BADA MANDIA* ADOPTION AND INFLUENCE ON YIELD FROM DOUBLY ROBUST MODELS

(kg/ha)

Item	IPWRA			AIPW		
	Logit	Probit	Heteroscedastic probit	Logit	Probit	Heteroscedastic probit
(1)	(2)	(3)	(4)	(5)	(6)	(7)
PO means Untreated	1130.7	1143.67	1144.04	1134.65	1153.39	1152.42
PO means (Treated)	1891.49	1903.49	1901.37	1893.17	1908.31	1904.16
ATE (Treated vs Untreated)	760.79	759.82	757.33	758.52	754.92	751.74
Outcome equation (TE) for Untreated farmers (OME_0)						
REF	0.957	0.946	0.906	0.901	0.900	0.913
LHS	4.813*	4.726*	4.618*	4.871*	4.876*	4.916*
GAP	10.086	10.637	10.425	10.121	10.108	10.006
FE	1.511*	1.501*	1.498*	1.516*	1.518*	1.519*
AMI	7.008	7.025	8.169	7.108	7.117	7.004
Constant	1125.09**	1151.38**	1138.21**	1158.11**	1148.91**	1159.32**
Outcome equation (TE) for Treated farmers (OME_1)						
REF	2.035**	2.044**	2.114**	2.016**	2.011**	2.009**
LHS	5.627**	5.782**	5.812*	5.865**	5.891**	5.801*
GAP	31.289**	32.869**	32.921**	30.144**	31.099**	31.116**
FE	1.924**	2.086**	2.118**	2.114**	2.816**	2.731**
AMI	13.285**	14.812**	14.954**	14.142**	14.215**	14.361**
Constant	1886.27**	1898.26**	1829.28**	1801.31**	1800.01**	1803.17**
Selection equation - Heteroscedastic Probit Model (TME_1) –						
REF			2.065**			2.071**
LHS			4.912			4.996
LHS^2			1.628			1.621
GAP			25.241**			25.002**
FE			1.682*			1.703**
AMI			10.254*			10.316**
Constant			1289.72**			1271.17**

Note: ** and * indicate ‘Z’ statistical significance at 1 and 5 per cent levels respectively.

TABLE 12: PREDICTED PROBABILITY OF *BADA MANDIA* ADOPTION AND INFLUENCE ON NET INCOME FROM DOUBLY ROBUST MODELS

(Rs./ha)

Item	IPWRA			AIPW		
	Logit	Probit	Heteroscedastic probit	Logit	Probit	Heteroscedastic probit
(1)	(2)	(3)	(4)	(5)	(6)	(7)
PO means (Untreated)	19007.07	18834.01	18901.39	19058.48	19157.02	18937.86
PO means (Treated)	30324.39	30214.58	30296.11	30423.64	30530.18	30328.07
ATE (Treated vs Untreated)	11317.32	11380.57	11394.72	11365.16	11373.16	11390.21
Outcome equation (TE) for Untreated farmers (OME_0)						
REF	1.822	1.818	1.802	1.778	1.797	1.811
LHS	1.822*	1.841*	1.803*	1.811*	1.819*	1.866*
GAP	4.442	4.321	4.389	4.225	4.218	4.221
FE	7.926*	7.912*	7.903*	7.226*	7.281*	7.193*
AMI	1.963	2.117	1.998	1.895	1.903	1.892
Constant	18128.67**	18212.38**	18132.24**	18235.41**	18234.58**	18235.99**
Outcome equation (TE) for Treated farmers (OME_1)						
REF	8.105**	8.117**	8.204**	8.115**	8.022**	8.111**
LHS	2.307**	2.312**	2.348*	2.399**	2.418**	2.384*
GAP	7.092**	7.119**	7.129**	7.011**	7.126**	7.147**
FE	7.282**	7.312**	7.361**	7.360**	7.395**	7.388**
AMI	3.305**	3.376**	3.388**	3.158**	3.166**	3.159**
Constant	29985.37**	29049.21**	28911.29**	29044.78*	29026.84**	28949.82**
Selection equation - Heteroscedastic Probit Model (TME_1) –						
REF			8.196**			8.056**
LHS			2.114			2.358
LHS^2			0.488			0.471
GAP			7.058**			7.085**
FE			7.104**			7.120**
AMI			3.452**			3.491**
Constant			20618.12**			203979.53**

Note: ** and * indicate 'Z' statistics significance at 1 and 5 per cent level respectively.

and FE significantly affect finger millet yield and net income across the selected models. However, for treated farmers, in addition to these, REF, GAP, and AMI also exerted a significant impact on the outcome variables. This clearly demonstrates that REF linkages, knowledge and adoption of GAP and AMI technologies contribute to higher yields and net income among treated farms, which can ultimately alleviate poverty among treated farms. These findings align with previous studies conducted by Fasakin *et al.*, 2022; Rahman and Connor, 2022; Sadique *et al.*, 2022; Richard *et al.*, 2020; Sseguya *et al.*, 2021.

IV

CONCLUSIONS

The potential impact of adopting the *Bada Mandia landrace* on small-holder yield and net income of farmers was studied by using PSM technique to address counterfactual situations. Further, using this econometric technique (IPWRA and

AIPW), a positive and significant impact of the adoption of *Bada Mandia* on the yield and net income of treated farmers was observed. These findings give credence to PSM results. The following strategies can be taken up from the study:

- Research on testing the yield attributing characteristics including crop production and plant protection performance of *Bada Mandia* should be done by Government and Research institutes including OUAT.
- Market-led extension services, leveraging Information and Communication technology and media systems should be strengthened. Extension functionaries should also target untreated farmers for the adoption of *Bada Mandia* technology.
- Efforts should be made to create a favourable micro-environment that facilitates easy access to *Bada Mandia*, which in turn achieved through fostering productive relationships among the research stations, farmer producer organizations, and the Government to supply quality seed to farmers at affordable prices.

REFERENCES

Adeyemi, A. A., Omotara, O. A., Adeyemo, A. A. and Oludele, A. S. (2020). Impact of improved rice varieties' adoption on sustainable rice productivity among farmers in Southwestern Nigeria. *Int. J. Adv. Res. Biol. Sci., 7*(4), 69-78.

Akinrinola, O.O., and Adeyemo, A.O. (2018). The Impact of Agricultural Technology Adoption on Poverty: The Case of Yam Minisetts Technology in Ekiti State, Nigeria. *J Agri Res, 3*(9), 000195.

Ali, A., and O. Erenstein (2017), "Assessing Farmer Use of Climate Change Adaptation Practices and Impacts on Food Security and Poverty in Pakistan*" Climate Risk Management*, Vol.16, pp. 183-194. https://doi.org/10.1016/j.crm.2016.12.001

Dar, M.H., Waza, S.A., Shukla, S., Zaidi, N.W., Nayak, S., Hossain, M., Kumar, A., Ismail and A.M., Singh, U.S. (2020). Drought tolerant rice for ensuring food security ineastern India. *Sustainability* 12 (6), 2214. https://doi.org/10.3390/su12062214

Fasakin, I.J., Ogunniyi, A.I., Bello, L.O., Mignouna, D., Adeoti, R., Bamba, Z., Abdoulaye, T. and Awotide, B.A. (2022). Impact of Intensive Youth Participation in Agriculture on Rural Households' Revenue: Evidence from Rice Farming Households in Nigeria. *Agriculture 2022, 12*, 584.https://doi.org/10.3390/agriculture12050584

Foster, J., Greer, J. and Thorbecke, E. (1984). A class of decomposable poverty measures. *Econometrica, 52*, 761-766.

Glynn, A.N. and Quinn, K.M. (2010). An introduction to the augmented inverse propensity weighted estimator. *Political Analysis 18*, 36–56.

Gupta, S.M., Arora, S., Mirza, N.,Pande, A., Lata, C., Puranik, S.,Kumar, J. and Kumar, A. (2017). Finger Millet: A "Certain" Crop for an "Uncertain" Future and a Solution to Food Insecurity and Hidden Hunger under Stressful Environments. *Front. Plant Sci. 8*, 643.doi: 10.3389/fpls.2017.00643

Mottaleb, K.A., Rejesus, R.M., Murty, M., Mohanty and S., Li, T. (2017). Benefits of the development and dissemination of climate-smart rice: ex ante impact assessment of drought-tolerant rice in South Asia. *Mitig. Adapt. Strategies Glob. Change* 22, 879–901. https://doi.org/10.1007/s11027-016-9705-0

Government of Odisha (2021), *Odisha Agriculture Statistics 2018-19*, Department of Agriculture and Farmers' Empowerment, Bhubaneswar.

Government of Odisha (2022), *Odisha Agriculture Statistics 2020-21*, Department of Agriculture and Farmers' Empowerment, Bhubaneswar.

Laan, Van der, M. J. and D. Rubin (2006). Targeted maximum likelihood learning. U.C. Berkeley Division of Biostatistics Working Paper Series. http://www.bepress.com/ucbbiostat/paper213/.

Panda, D., Panda, A., Prajapati, H., Behera, P. K., Nayak, J. K., Lenka, K. C. and Parida, P. K. (2022). Genetic variability of panicle architecture and nutritional parameters in indigenous finger millet genotype from Koraput, Eastern Ghats of India. Cereal Research Communications, December 2022. DOI: https://doi.org/10.1007/s42976-022-00345-3

Philips, D., Masangwa, M. and Philip, B. (2000). Adoption of maize and related technologies in the north-west Zone of Nigeria. *Moor J. Agric. Res.,1*, 98-105.

Rahman, M. M. and Connor, J.D (2022). The effect of high-yielding variety on rice yield, farm income and household nutrition: evidence from rural Bangladesh. Agriculture & Food Security, 11:35. https://doi.org/10.1186/s40066-022-00365-6

Richard Kwasi Bannor, Gupta Amarnath Krishna Kumar, Helena Oppong-Kyeremeh and Camillus Abawiera Wongnaa. (2020). Adoption and Impact of Modern Rice Varieties on Poverty in Eastern India, *Rice Science*, 27(1): 56í66. https://doi.org/10.1016/j.rsci.2019.12.006

Sadique, Rahman Md., Md. Hayder Khan Sujan, Debasish Chandra Acharjee, Rezoyana Kabir Rasha and Mofasser Rahman. (2022), Intensity of adoption and welfare impacts of drought-tolerant rice varieties cultivation in Bangladesh, Heliyon 8 e09490.https://doi.org/10.1016/j.heliyon.2022.e09490

Sseguya H, Robinson DS, Mwango HR, Flock JA, Manda J and Abed R. (2021), “The Impact of Demonstration Plots on Improved Agricultural Input Purchase in Tanzania: Implications for Policy and Practice”, *PLoS ONE* 16(1): e0243896. https://doi.org/10.1371/journal.pone.0243896

Wooldridge, J.M. (2007), “Inverse Probability Weighted Estimation for General Missing Data Problems”, *Journal of Econometrics. Vol.*141, No. 2, pp. 1281–1301.