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Determinants of Adopting Improved Lentil Management Practices through Locally Developed Bed Planter in Bangladesh

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ABSTRACT

This study investigated adoption and determinants of adopting the bed planter developed by Bangladesh Agricultural Research Institute (BARI) and the impacts on productivity and farm income in the Rajshahi and Faridpur districts of Bangladesh. Primary data were collected during 2019 from 41 adopters and 80 non-adopters using a multi-stage random sampling technique. On average, the adoption rate of the BARI bed planter was 15%. Socio-economic characteristics such as farm size, farming experience, training, and extension contacts significantly differed between adopters and non-adopters. A probit model showed that farmer experience, extension contacts, and farmers' club membership were key variables influencing the likelihood of BARI bed planter adoption. Policy recommendations based on these results include modifying current extension approaches and increasing investment in farm machinery.

Keywords: Bangladesh Agricultural Research Institute, Farm machinery, Farmers' club, Probit model.

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INTRODUCTION

Rural poverty may be addressed using technology that improves productivity, such as the use of scientifically recommended quality inputs and adoption of improved management practices (Ghimire *et al*., 2015). Some farmers are reluctant to follow management practices recommendations, such as limited/no-tillage, crop rotation, irrigation, seedlings, manure and fertilization practices, proper application of pesticides, weed management, and use of farm machinery. The average farm size in Bangladesh is 0.004 ha per farm holding, with most farms (84.27% of total holdings) considered marginal (0.25 to 0.40 ha) or small (0.41 to 1.01 ha). Land holdings are often fragmented and scattered across different plots (3.2 pieces of land per household, on average), resulting in limited use of mechanization and adoption of new technologies (Mottaleb *et al*., 2017; BBS, 2020).

Lentil is a staple pulse in most Asian countries and constitutes 40.23% of total pulse crop cultivation in Bangladesh, making it the most popular pulse crop in

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Bangladesh by consumer preference and total consumption (BBS, 2019). Bangladesh consumes 0.5 million tons of lentils per year at a rate of approximately 17 gm per capita per day, far below the 45 gm per day recommended by the World Health Organization (FAO, 2011). To become self-sufficient in lentil production, the government and other institutions throughout Bangladesh are working on various development and lentil improvement programs, such as those promoting the adoption and use of scale-appropriate machinery. The Bangladesh Agricultural Research Institute (BARI) has developed and attempted to distribute a scale-appropriate multi-crop planter to farmers for cultivation of lentil and other crops (wheat, maize, potato, mungbean, okra, lentil, chili, black gram and sesame). The BARI bed planter can be used in small plots, reduces the labor costs of bed formation and seeding time, and should result in higher yields and farm income (Karim *et al*., 2017). Although this technology is suitable for farmers in Bangladesh, its adoption rate is low (15%) and the factors affecting adoption have not yet been identified.

Studies on the adoption of improved management practices, improved varieties (Miah *et al*., 2004; Mahmud *et al*., 2014; ICARDA, 2018), and the profitability and production of pulses have varied findings and conclusions (Nain *et al*., 2014; Kumbhare *et al*., 2014; Mottaleb *et al*., 2017; Karim *et al*., 2017; Yi, 2018; Akram *et al*., 2020; Takeshimaa *et al*., 2020; Moniruzzaman *et al*., 2021). A major limitation of previous studies is that they analyzed either improved variety adoption and productivity, or the use of individual management techniques or farm machinery, which does not comprehensively explain why farmers fail to adopt farm machinery in general. Therefore, the goal of this study was to investigate: (a) The factors affecting mechanization adoption, and (b) The impact of mechanization on lentil productivity and farm income.

MATERIALS AND METHODS

Selection of Study Areas

Faridpur, Jessore, Khustia, Pabna, and Rajshahi are the major lentil growing areas in Bangladesh. This study focused on the Rajshahi district in west-central Bangladesh and the Faridpur district in south-central Bangladesh due to their lentil production potential and presence of the BARI bed planter. The total lentil cultivated area in Bangladesh was 142,481.8 ha, of which the Rajshahi district constituted 17,842.51 ha (13%) and the Faridpur district constituted 16,892.71 ha (12%) (BBS, 2019). The total lentil production in Bangladesh was 175,384 tons, of which the Rajshahi district contributed 22,627 tons (13%) and the Faridpur district contributed 28,745 tons (16%) (BBS, 2019).

To minimize selection bias, the study areas were selected based on lentil cultivation intensity, also known as the Lentil Area Index (LAI). LAI was calculated as suggested by Nazu *et al*. (2021):

$$LAI = \left(\frac{AL}{AC}\right) * 100 \quad (1)$$

Where, AL is the Lentil Area and AC is the gross Cropped Area. Lentil-growing districts were classified as: (i) High-intensity areas (LAI> 76.0), such as Rajshahi, Faridpur, and Natore; (ii) Medium intensity areas (LAI= 38.0 to 76.0), such as Jhenaidah, Pabna, Jashore, Kushtia, Rajbari, and Meherpur; and (iii) Low intensity areas (LAI< 38.0), such as Madaripur, Narail, Gopalganj, Magura, Sirajganj, Shariatpur, Chapai Nawabganj, Chuadanga, and Barishal (Figure 1).

Sampling Technique and Sample Size

A multi-stage, purposive sampling procedure was adopted. During the first stage, Rajshahi and Faridpur were considered based on LAI and selected as locations where both the BARI bed planter and traditional technologies are used. During

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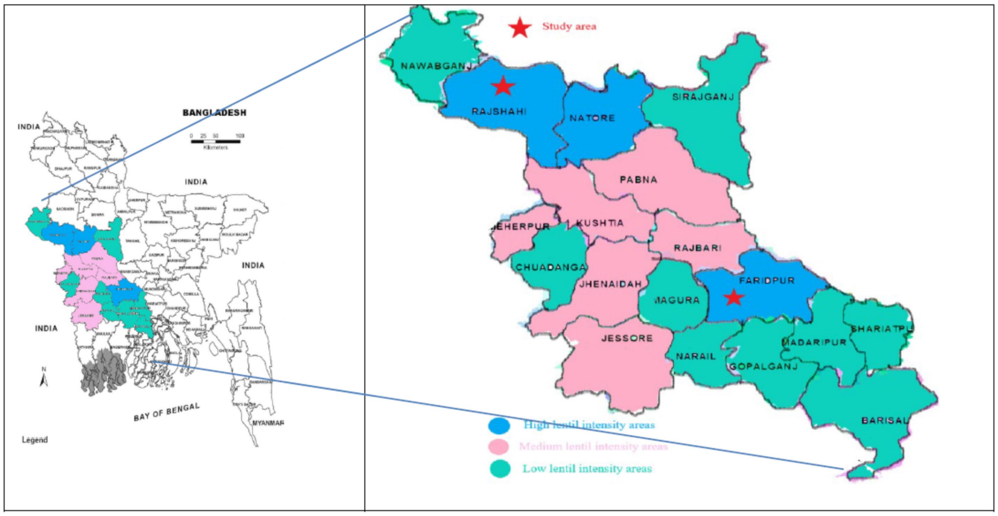

Figure 1. The major lentil growing areas in Bangladesh. Study areas are marked with stars.

the second stage, four Upazilas (formerly called a Thana, an Upazila is an administrative region in Bangladesh, functioning as a sub-unit of a district) (Godagari, Poba, Durgapur and Charghat) from Rajshahi and one Upazila (Sadar) from Faridpur (due to the availability and use of the BARI bed planter), and one union (lower-level administrative unit) from each Upazila were selected. Then, a complete list of lentil growers using the BARI bed planter in each Upazila was prepared with the help of the Sub-Assistant Agriculture Officer of the Department of Agriculture Extension (DAE) and the Regional Agricultural Research Institute, Rajshahi and Faridpur. A total of 121 farmers were interviewed, consisting of 41 adopters and 80 non-adopters. Of the adopters interviewed, 34 were from Rajshahi and seven were from Faridpur. A structured questionnaire was prepared and pre-tested. The primary data were collected through personal interviews from February to March 2019.

Analytical Techniques

Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to analyze and compare the socio-economic characteristics and institutional variables between adopters and non-adopters of the BARI bed planter.

Econometric Analysis

A probit regression model was used to estimate the determinants of BARI bed planter adoption in lentil farming. After the probit regression, the region of common support was selected, and a balance test was conducted to match the similarities of the sub-sample of control cases with the treated cases. Using the estimated propensity scores, the mean difference of outcome was considered as the treatment effect of BARI bed planter adoption. The effect of BARI bed planter adoption on productivity and income of farm households were estimated through two different methods: the nearest neighbor and kernel-based matching methods. The propensity score matching model was expressed as:

$$P(X) = \Pr\left[D = \frac{1}{X}\right] = E\left[\frac{D}{X}\right] \quad (2)$$

Where, D= [0,1] is an indicator of BARI bed planter adoption, and X denotes a vector of pre-adoption (observed) characteristics. The propensity scores were estimated using the probit or logit models with the Dependent variable (D) coded as 1 for BARI

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bed planter adopters (treated observations) and 0 for BARI bed planter non-adopters (control observations). After the propensity score was calculated, the Average Treatment effect on the Treated (ATT) was estimated as follows:

$$ATT = E\{Y_i^1 - Y_i^0 \mid D = 1\},$$
$$ATT = E[E\{Y_i^1 - Y_i^0 | D_i = 1, \rho(X)\}]$$
$$ATT = E[E\{Y_i^1 | D_i = 1, \rho(X)\}] - E\{Y_i^0 | D_i = 0,\ \rho(X)\} \mid \text{D=1}] \quad (3)$$

Where, Y_i^1 and Y_i^0 are the potential outcomes in the two counterfactual situations of treatment and no treatment, respectively. Once the propensity scores were estimated, each adopter was matched to a non-adopter with a similar propensity score to estimate the ATT. Prior to the analysis, a correlation test was used to check for multicollinearity among the explanatory variables. Variable multicollinearity was not a concern since the correlation coefficient was less than 0.4.

RESULTS AND DISCUSSION

Adoption Rate

Although the BARI bed planter is a scale appropriate farm mechanization device, its field level adoption was low, with an average adoption rate of approximately 15% (Table 1). The highest adoption rate was recorded in Rajshahi farmers (17.18%). The majority of the farmers mentioned a lack of availability of the machine in peak use periods, capital constraints, and seed meter problems as the major factors hindering their adoption of BARI bed planter. Additionally, many farmers had difficulty operating the bed planter due to a lack of training facilities, resulting in lower adoption (DAE, 2019).

Characteristics, Costs, and Returns of Adopters and Non-Adopters

The average age of the sampled farmers was slightly higher for BARI bed planter adopters than non-adopters (Table 2). The average family size was slightly greater for adopters (5.24 persons/household) than non-adopters (5.08 persons/household), which were both higher than the national average (4.5 persons/household). Adopters had 5.13 more years of farming experience than non-adopters, on average. By owning large farm holdings, farmers may be reluctant to increase their production through adopting new technologies, which may explain why farm size was significantly higher for non-adopters than adopters, as found in previous studies (Moser and Barrett, 2002; Cornejo *et al*., 2002; Bravo-Ureta *et al*., 2006; Gedikoglu, 2010; Chahal *et al*., 2014). However, medium and small farm holders aspire to increase their productivity for family needs and to increase farm income. The majority of the BARI bed planter adopters had more extension contacts and training than non-adopters. Membership in a farmers' club may influence a farmer's decision to adopt a particular technology, as adopters had greater affiliation to farmers' clubs than non-adopters. Potential yield loss due to environmental factors, measured as the difference between a farmer's expected yield and actual yield, was higher for non-adopters than adopters. In summary, adopters had significantly lower farm size and potential yield loss, greater farming experience, training, extension contacts, and group membership than non-adopters. This finding is consistent with previous research

Table 1. BARI bed planter adoption rate for lentil cultivation at the farm level.

Crops	Location	Percentage of farmers
Lentil	Rajshahi (n= 34)	17.18
	Faridpur (n= 7)	4.58
	All (n= 41)	15.03

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Table 2. Characteristics, cost and returns of adopters and non-adopters of BARI bed planter.

Variable	Adopter	Non-adopter	Difference	t-Value
Age	43.73	43.4	0.332	0.139
Education	6.05	5.85	0.199	0.226
Family size	5.24	5.08	0.169	0.534
Farm size	77.58	101.25	-23.67	-1.809**
Farming experience	14.27	9.14	5.131	3.584***
Training	0.95	0.84	0.114	1.806**
Extension contacts	2.63	2.3	0.334	2.367***
Farmers' club membership	0.341	0.138	0.204	2.678***
Potential crop loss due to environmental factors	1.342	1.813	-0.471	-2.535***
Yield (kg ha^{-1})	1,974.01	1,576.82	397.188	4.000***
Price (Tk kg^{-1})	51.67	51.31	0.351	0.295
Gross return (Tk ha^{-1})	1,02997.20	81,467.52	2,1529.68	1.892**
Total variable cost (Tk ha^{-1})	39,416.85	42,207.34	-2790.49	-2.581***
Total cost (Tk ha^{-1})	50,842.11	54,773.47	-3931.36	-3.112***
Gross margin (Tk ha^{-1}) (3-4)	63,580.35	39,260.18	24,320.17	2.640***
Net return (Tk ha^{-1}) (3-5)	52,155.09	26,694.05	25,461.04	3.021***
Rate of return				
Over variable cost (3÷4)	2.61	1.93	0.68	3.502***
Over total cost (3÷5)	2.03	1.49	0.54	3.868***

** and ***: Indicate significance at the 5 and 1% levels, respectively.

that reported that growers using improved pulses had significantly higher levels of education, agricultural training, and extension contacts (Rahman *et al*., 2018).

The average lentil yield was significantly greater for adopters (1.97 t ha^{-1}) than non-adopters of the BARI bed planter (1.58 t ha^{-1}) (Table 2). For reference, the national average lentil yield is 1.3 t ha^{-1} (Alam *et al*. 2017) and a previous study found an average pulse yield of 1.28 t ha^{-1} (Rahman *et al*., 2018). The average net return was significantly greater (by 48.81%) for adopters (Tk. 52,155.11 per ha) than non-adopters. The BCRs were significantly greater for adopters than non-adopters, which is consistent with previous research and indicates that technology adoption significantly affects profitability (Rahman *et al*., 2018; Gireesh, 2019; Islam *et al*., 2020).

Determinants of Adoption

The probit model estimates indicated a good fit to model criteria, as the pseudo value ranged between 0.2 and 0.4 (McFadden, 1979), and indicated that five explanatory variables influenced BARI bed planter adoption in lentil cultivation (Table 3). There was a significant negative relationship between farmer age and BARI bed planter adoption probability (one year increase in farmer's age, the probability of adoption decreased by 0.9%), which is consistent with previous research (Lambrecht *et al*., 2014; Lencses *et al*., 2014; Ghimire and Huang, 2016; Ali, 2017). Lentil cultivation experience of household heads significantly affected BARI bed planter adoption (P= 0.000), with a unit increase in farming experience increasing the probability of BARI bed planter adoption by 2.65%. The finding is logical considering that the knowledge of experienced farmers is likely to give insight as to the best management practices to adopt, and consistent with previous research (Chandio and Yuansheng, 2018; Afolami *et al*., 2015). Access to extension service had a statistically significant (P= 0.077) effect on BARI bed planter adoption, with a unit increase in farmers' access to extension services increasing the probability of BARI bed planter adoption by 12.84%. The finding is consistent

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Table 3. Probit analysis of the factors influencing BARI bed planter adoption in lentil cultivation.[a]

Variables	Coefficients	Std Error	Z value	Pr (> |Z|)	Marginal effects (dy/dx)
Constant	-0.1181	1.080	-0.11	0.913	
Household characteristics					
Age of household head (Years)	-0.0266*	0.014	-1.93	0.054	-0.0092
Household size (NO)	-0.0532	0.086	-0.61	0.539	-0.0183
Education of household head (Years)	-0.0557	0.038	-1.48	0.140	-0.0192
Farm characteristics					
Farming experience in lentil cultivation (Years)	0.0769***	0.021	3.6	0.000	0.0265
Institutional characteristics					
Access to extension services	0.3725*	0.210	1.77	0.077	0.1284
Training access	0.0565	0.507	0.11	0.911	0.0192
Farmers' club	0.8133**	0.341	2.39	0.017	0.3024
Environmental factors					
Potential yield loss due to environmental factors	-0.4009***	0.155	-2.58	0.010	-0.13819
Location dummy					
Rajshahi region	-0.3458	0.3815	-0.91	0.365	0.0923

[a] Number of obs= 121; Log likelihood= -59.949; LR Chi^2 (10)= 35.05 Prob> Chi2= 0.0001; Pseudo R2= 0.2262; Wald Chi-square= 28.08 (9); Probability (P) = 0.0009.
*, **, and ***: Indicate significance at the 10, 5, and 1% levels, respectively.

with the results of Yigezu *et al*. (2018). Farmers' club membership had a significant, positive influence on BARI bed planter adoption, as members of farmers' clubs were 30.24% more likely to adopt the BARI bed planter (P= 0.017) than non-members. As a place where farmers acquire skills and share knowledge on agricultural information and technologies, farmers' clubs represent an important form of social capital. This finding is consistent with the results of Diallo *et al*. (2020). The coefficient of potential yield loss due to environmental factors, such as insect damage, heavy rain, drought, fog, and extreme cold, was significantly negatively correlated with BARI bed planter adoption. Potential yield losses were lower for adopters than non-adopters, and for each unit increase in yield loss, BARI bed planter adoption increased by 13.81%.

Impact on Lentil Productivity

BARI bed planter adoption significantly affected lentil productivity. According to the nearest neighbor matching method, lentil productivity was 247.38 kg ha^{-1} greater for adopters than non-adopters (P< 0.10) (Table 4). Figure 2 shows the propensity score matching by BARI bed planter adoption for lentil farmers. Using the Kernel-based matching method, the effect of the BARI bed planter technology on lentil productivity was positive and significant (P< 0.05) (Table 4). The ATT estimates suggest that BARI bed planter adoption significantly increased lentil productivity by 297.48 kg per ha. Similarly, an ATT study in the mid-hills of Nepal found a positive impact of mini-tiller adoption on rice productivity (Paudel *et al*., 2019). Results provide evidence that BARI bed planter adoption increased the lentil productivity of adopters.

Impact on Farm Income

The ATT estimates of average annual income from the nearest neighbor Based on an exchange rate of 1 US$= 92.43 BDT (Taka) (BDT. 55465.29/year) and Kernel-based matching methods (BDT. 64290.08/year) were statistically significant

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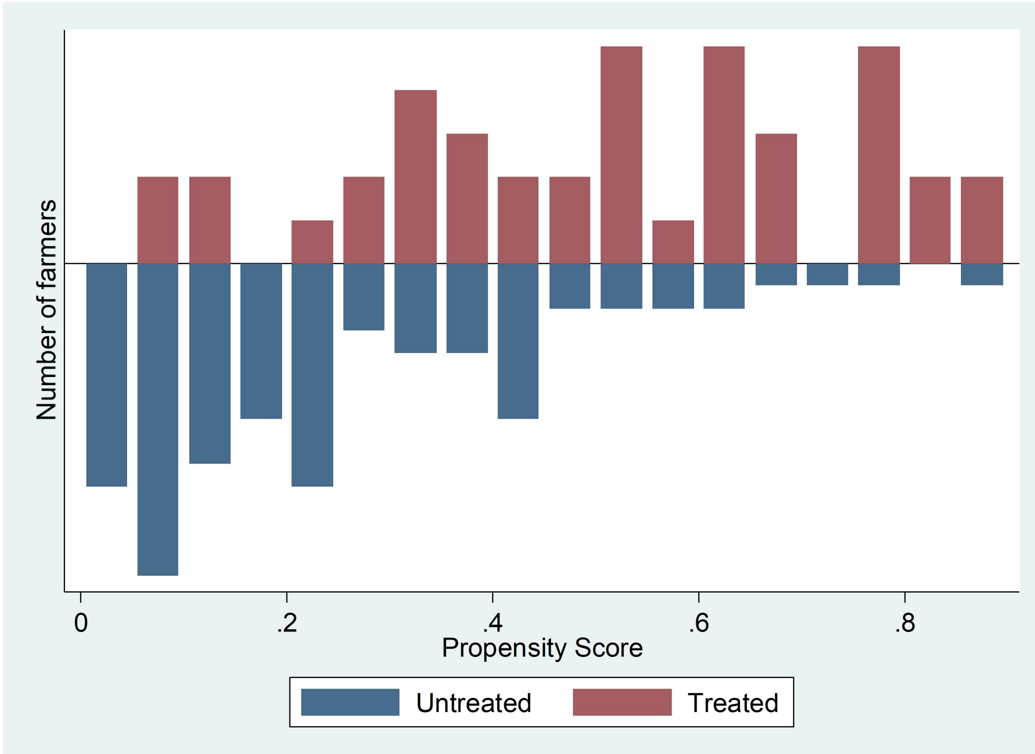

Figure 2. Propensity score matching by BARI bed planter adoption for lentil farmers.

Table 4. Impact of the BARI bed planter on lentil productivity and income.

Outcome variable	Number of samples		ATT	SE	t-Value
	Adopters (N)	Non-adopters (N)			
Productivity					
NN matching	41	22	247.38*	153.72	1.61
Kernel matching	41	66	297.48**	128.82	2.31
Income					
NN matching	41	22	55465.29*	33869.77	1.64
Kernel matching	41	66	64290.08**	28666.32	2.24

* and **: Indicates significance at the 10 and 5% levels, respectively.

at the 10 and 5% probability levels, respectively (Table 4). These findings suggest that using a BARI bed planter increases lentil farm income. Using a BARI bed planter in lentil farming

could improve soil quality due to the presence of crop residues, reduce time spent on sowing and harvesting, reduce costs, and increase farm income and productivity. Previous research has also found improvements in household or farm income due to the adoption of technology, as in the case of improved seeds and tractors in a study from Mozambique (Cunguara and Darnhofer, 2011) and improved agricultural technologies in a study from Ethiopia (Wordofa *et al*., 2021).

CONCLUSIONS

The BARI-developed presents an opportunity to increase agricultural productivity in Bangladesh. Shifting from a

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conventional to a partially mechanized production system in lentil farming increased net revenue per ha by 48.81%. Young farmers were more likely to adopt BARI bed planters than older farmers, and the BARI bed planter improved lentil cultivation by 64% to 124% compared to traditional production. The adoption rate of BARI bed planters remains low, making it necessary for scientists, private industry, and the government to play a role in planning and executing technology-related programs, introducing training programs, and supporting extension services to motivate farmers and disseminate information. The efficacy and advantages of improved farm management practices, especially new technologies such as the BARI bed planter, should be communicated through frequent farm visits of extension agents.

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عوامل تعیین کننده کاربرد شیوه‌های مدیریت بهبود یافته عدس با استفاده از پشته-کارساخته شده محلی در بنگلادش

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چکیده

هدف این پژوهش بررسی پذیرش کشاورزان وعوامل تعیین‌کننده استفاده از پشته‌کارساخته شده محلی توسط موسسه تحقیقات کشاورزی بنگلادش (BARI) و تأثیرات آن بر بهره‌وری و درآمد مزرعه در مناطق Rajshahi و Faridpur بنگلادش بود. داده های اولیه در طول سال ۲۰۱۹ از ۴۱ کشاورز پذیرنده و ۸۰ غیر پذیرنده با استفاده از روش نمونه گیری تصادفی چند مرحله ای جمع آوری شد. به طور میانگین، نرخ پذیرش پشته‌کار BARI ۱۵٪ بود. ویژگی‌های اقتصادی-اجتماعی مانند اندازه مزرعه، تجربه کشاورزی، آموزش، و تماس‌های ترویجی به گونه قابل‌توجهی بین پذیرندگان این وسیله و غیرپذیرندگان متفاوت بود. یک مدل پروبیت (Probit model) نشان داد که تجربه کشاورز، تماس‌های مروج و عضویت در باشگاه کشاورزان متغیرهای کلیدی هستند که بر احتمال پذیرش پشته‌کار BARI تأثیر می‌گذارند. توصیه‌های سیاستی مبتنی بر این نتایج شامل اصلاح رویکردهای ترویجی و توسعه کنونی و افزایش سرمایه‌گذاری در ماشین‌آلات کشاورزی است.

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