Is a Training Program Sufficient to Improve the Smallholder Farmers’ Productivity in Africa? Empirical Evidence from a Chinese Agricultural Technology Demonstration Center in Tanzania

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Abstract: The article aims to analyze the effect of training programs on the yield of smallholder farmers. The empirical analysis employed a sample of data collected from a rice farming household in the Mvomero district of Tanzania. The results indicate that the yield outcome among trained and non-trained farmers with water access for irrigation was significantly more than double; however, the yield difference between trained and non-trained farmers was insignificant in non-irrigated plots. Our findings have policy implications for agricultural development in developing countries where training programs alone may not be a panacea for smallholder farmers’ productivity improvement. Therefore, respective governments, policymakers, and other agricultural stakeholders, should consider both farm and non-farm factors altogether, which may increase agricultural training effectiveness to address the challenges of low yields.

Keywords: China-Africa cooperation; agricultural program; agricultural training; technology adoption

1. Introduction

The majority of the world’s poor and undernourished people live in rural areas of developing countries. Often these people depend on agricultural activities for most of their lives. Agriculture plays an important role, not only as a source of food and household income, but also in contributing to economic development. In Tanzania, the agricultural sector contributes about 27% of Gross Domestic Product (GDP) and 67% of total employment [1]. However, despite an average growth rate of 4.4%, the country’s agricultural sector is still characterized by traditional agriculture and its methods that cannot bring real change in contributing to more significant wealth creation and poverty reduction [2].

The low adoption of new agricultural technology may be linked to various factors, such as new technology not being profitable in the farmers’ context, infrastructures that are not supportive, lack of enough money to purchase technology (even if it is profitable), or unwillingness of farmers to try due to risk it entails [3,4]. Still, the need for upscaling agricultural technology in Tanzania can never be undervalued because technological change is necessary for the development process [5]. The Tanzanian agricultural sector needs to grow at an average growth rate of around 6 to 8% to play a significant role in poverty reduction and increasing wealth [6,7].
The Tanzanian government’s strategy to bring about greater efficiency in the agricultural sector includes strengthening various agricultural development strategies and technical cooperation, with local and international development partners to increase awareness and make technology easier to access. Tanzania is among the African countries that benefited from constructing the Agricultural Technology Demonstration Center (ATDC) between 2009 and 2013. The ATDC is a Chinese-funded program to promote agricultural technology and share Chinese farming experiences with Africa. Approximately USD $130 million was funded through a China–Africa cooperation to facilitate the construction of about 23 ATDCs across Africa to improve agricultural production and food security in rural areas. The program benefited Tanzanians with one ATDC located at Dakawa, which was constructed from 2009 to 2011, and cost about USD $6 million.

The demonstration, based on Chinese expert perspectives, implies doing on-station comparison studies and pilot research, generally within the compound of ATDC, to present how Chinese technology may perform in an African context [8]. In the initial trial of experimental plots in the station, the rice yields with Chinese hybrids were four times higher than that of local varieties [9]. However, the Chinese hybrid varieties were then neither locally reproduced nor disseminated to farmers due to intellectual property rights, seed regulation, and phytosanitary procedures [10]. Besides, experiment trials revealed that Chinese farm technology alone could contribute 20% to 30% of productivity improvement for the local rice varieties than traditional methods [11]. Thus, the actual rice technology received by farmers from ATDC was limited to their recommended rice management practices from seedling to harvesting, disseminated via training, and demonstration in helping farmers improving rice productivity in Tanzania.

Nevertheless, Tanzania has continued to increase agricultural production and reduce food insecurity in recent years, but much more needs to be done. The country ranks second in rice production in Eastern and Southern Africa after Madagascar, and in the country, rice is the second staple food and commercial crop after maize. Nevertheless, rice productivity in Tanzania is still unsatisfactory. While Senthilkumar [12] reported the rice yield gap as high as 87%, the Food and Agriculture Organization of the United nations (FAO) statistic data indicate that the rice yield per hectare is lower (1.6–2.7 MT/ha) because most of the harvest is still dependent on rainfall during the growing season. In contrast to the few areas available for irrigation schemes, higher average yields (5–6 MT/ha) have been found [13]. Yet, nearly 71% of produced rice within the country relies on rainfall cultivation by smallholder farmers, constituting about 80% of the country’s farmers. These small farmers usually cultivate an average of 0.2 to 3.0 hectares. However, they are experiencing weather variability while facing limited long-term strategies and investment in agricultural production due to the lack of financial capacity of the farming households. They therefore continue to experience limited technology that prevents them from achieving high yields.

Many farmers nowadays still relying on traditional methods that may be ineffective for rice production, and, thus, they continue to be small-scale producers, mostly to feed their families, and what remains is sold to generate income. However, improving rice production remains the government priority in the rice industry strategy, by which Tanzania is visioning to become a significant rice exporter in Africa. Achieving rice production growth is an essential requirement that necessitates the technology transfer process and smallholder farmers’ adoption of rice yield increasing technology. However, researchers have shown that under the best condition, potential rice yields in Tanzania range from 4 to 6 MT/ha for uplands and 6 to 10 MT/ha for lowlands irrigated ecosystems of cultivation. Still, these levels of harvests always depend on the type of rice varieties and the level of management practices [13]. Therefore, agricultural training and advice are essential in enabling rice producers to realize potential productivity by giving them the proper tools, knowledge, and skills necessary.
To date, several national and international partners have been collaborating with the government to address this issue of low rice productivity of smallholder farmers in Tanzania. Agricultural training on rice cultivation practices has reached farmers through various extension services, such as village extension services under the district government office, the ministry of agriculture, agricultural research, training institutions, and Non-Governmental Organizations (NGOs). The field extension services are based on personal or group visits, scheduled farmers meetings, the use of key farmers (model farmer), farm demonstration plots, and lately, information and communications technology (ICT) application. It is argued that, in comparison to conventional farmers’ practices, with a set of good agricultural practices (GAP) in a participatory farm trial in 2013 and 2014, concerning growing seasons in representative irrigated and rainfed fields of Kilombero valley in Tanzania, farmers achieved a yield increase of 1 MT/ha in 2013 and 2.7 MT/ha in 2014 when farmers followed these rice cultivation practices. However, under rainfed conditions, the GAP impact on yield was not significant [12].

A five-year household-level panel data from 2008 to 2012 in Tanzania’s Ilonga irrigation scheme supports the finding that technology adoption increases immediately after training. Furthermore, non-trained farmers may catch up belatedly. In the case of technologies disseminated by Japan International Cooperation Agency (JICA) through project for supporting rice industry development in Tanzania (TANRICE) training, the paddy yield of the key farmers increased from 3.1 to 5.3 MT/ha, while ordinary farmers’ yield increased from 2.6 to 3.7 MT/ha (Nakano et al., 2018). Such findings indicate the effectiveness of training programs to increase the productivity of smallholder farmers.

Nevertheless, while literature considered the low adoption rate of high-yielding technology, and inputs (such as fertilizer) as barriers to a “Green Revolution” in sub-Saharan Africa [14–16], the impact of ATDC on farmers’ yield has not been evaluated empirically to bring insight into whether international agricultural technical assistance through the establishment of ATDCs may be an effective way to overcome these obstacles. At times, technology transfer is characterized by significant reticence and environmental sensitivity—this is worth considering for international agriculture technology transfer [17]. For instance, backward areas may require adaptive investments in the process of technology introduction and transfer to suit local agricultural production conditions. As such, this study is designed to understand the effectiveness of training, by the Chinese Agricultural Technology Demonstration Center, to improve yields of smallholder farmers in Tanzania.

Tanzania’s farmers have benefited from training and demonstration program on rice cultivation technologies provided by the Chinese Agricultural Technology Demonstration Center (ATDC) since 2011. The ATDC program aimed to improve food security in recipient countries by transferring Chinese technology via demonstration in farms, extension, and training from Chinese experts [18]. However, little is known regarding the effect of ATDC training in addressing the productivity of communities that participated in the projects. Previous studies on ATDC have focused on the concept of establishment of ATDC, situation, performance, and challenges, but the farmers’ side, as beneficiaries, required further investigation [8,10,19–24]. Thus, understand the impact of the ATDC program on beneficiaries yield improvement may assist with setting priorities, provide feedback to research programs, and guide policymakers and stakeholders involved in the process of technology transfer.

This study, therefore, utilizes representative household data collected in 2019 to contribute to the literature in two ways. First, it tests whether the farmer’s access to agricultural training will enhance the agricultural productivity of small farmers. Second, this paper examines the main factors that can encourage participation in agricultural training and the improvement of farm yield among rice farmers.

The rest of this paper is organized as follows. Section 2 is about material and methods used, which introduce the Tanzania ATDC program in brief, methodology, and data used in this study. Section 3 presents estimation results on the participation of smallholder farmers in agricultural training programs, factors affecting yields among trained and non-
trained farmers, training impact on technology adoption and rice yields of farmers, and the spillover effect of training programs. Section 4 concludes this study with some policy implications.

2. Materials and Methods

2.1. The Tanzania ATDC Program in Brief

The construction of Agricultural Technology Demonstration Center (ATDC) was initially announced in November 2006 at the Beijing Summit of China–Africa Cooperation, as a model for delivering agricultural aid. The criteria for establishing ATDC were based on the preliminary request from the government of a host country, comments from the Chinese embassy in a host country on the feasibility of the project, and tradition of cooperation between China and a host country. Tanzania followed the procedures and the protocols signed between China and Tanzania, one year after the summit, followed by the construction stage from 2009 to 2011. The ATDC was constructed in the Mvomero district in Dakawa, near the Tanzania Agriculture Research Institute (TARI–Cholima). The total area of ATDC is 62 ha, which includes three sections: office and training area (2 ha), experiment and display area (10 ha), and production and demonstration area (50 ha) with irrigation infrastructure. The overseer of the Chinese ATDC in Tanzania is a Chinese enterprise (Chongqing Sino-Tanzania Agricultural Development Co. Ltd.) and the Chongqing Academy of Agricultural Sciences in China, with the cooperation of the Tanzanian Ministry of Agriculture, Food Security, and Cooperatives (MAFC). The primary function of ATDC includes the research experiment of improved cultivars (hybrid and conventional rice, maize, horticulture, and banana) and techniques, training, and demonstration of the technology. However, ATDC in Dakawa has focused on rice, with various trials and demonstrations of the ten different hybrid rice cultivars from the Chongqing Academy of Agricultural Sciences, but also promotes agro-mechanization tools from China. China dispatched the modern agricultural equipment, including tractors, hollows, plows, rice harvesters, to be used in training and demonstration activities, to stimulate the interests of farmers to purchase similar products in the future.

The establishment of the Chinese Agricultural Technology Demonstration Center program in Tanzania may be summarized in three stages: the construction stage, technical cooperation, and business operation stage. The construction stage refers to the establishment of ATDC, held for two years (2009–2011) in Tanzania. The technical cooperation stage followed from 2011, after the establishment of ATDC. In the technical cooperation phase, the center began to implement the primary function of the center, which took place in three years. The ATDC training involved a combination of classroom, on-site, and video teaching, which aimed to spread modern agricultural knowledge on the use of new varieties and apply new technologies. The skills covered in the rice-training program include sowing and paddy seed preparation, leveling and water lodging prevention, nursery care, transplanting techniques, management of the soil nutrients, and fertilizer application. In the business stage, which is also known as the sustainable development phase, ATDC is required to establish a market-oriented operation and integrated agribusiness value chain to support ATDC operations without Chinese government grants. Currently, the ATDC in Tanzania is in a business stage that may take up to 12 years. In the technical cooperation and sustainable development phase, local farmers living in nearby villages have been organized for training in the center, particularly in sowing and harvesting seasons.

2.2. Modeling the Yield Effect of ATDC Training Program

The primary purpose of this paper is to assess the rice yield effect of the ATDC training program in a quasi-experimental setting using a cross-sectional dataset collected in Tanzania. The main challenge of quantifying the impact of a program, such as ATDC, is that we observe only what happens to beneficiaries who receive the training program; we do not observe what would happen to the same farmers if they did not receive training
from ATDC. Alternatively, the program would have been introduced in a randomized control design setting, where communities and households are randomly selected to receive the treatments (ATDC training program), where some would receive, and the rest would not. The households benefited from ATDC training were known as treated households; while the rest were known as control/untreated households. Apart from a randomized evaluation design, the study would apply a regression discontinuity design that requires a cut-line/threshold separating treated households and untreated households. However, a challenge that would arise is selection bias when treated households differ in some systematic way from untreated households, which would imply that those who choose to participate in ATDC training projects are already more likely to have better outcomes for reasons entirely other than their participation in the program. The randomization process would be suitable for internal validity as it could eliminate the validity threat of selection bias [25]. Thus, our ability to make a statement about the yield effect of the ATDC training program rests on how well we can address these main challenges of impact studies.

The method applied in this paper needs to address several issues given program intervention. First, we realize during the survey that the training program was disseminated to villages closer to ATDC without random distribution. Second, the ATDC model is based on farmers’ invitation to the ATDC, to access training from Chinese experts, yet the farming households who participated in the Tanzania ATDC program were not randomly selected from the village population. Third, there were no precise quantitative or qualitative mechanisms used in the selection of farming households that participated in the training program. These factors may bring a challenge of disentangling the yield impact of the ATDC program using our observational data. Yet, they make it feasible not to apply a randomized evaluation design and a regression discontinuity design in our evaluation analysis. Following Shiferaw et al. [26], when treatment groups are not randomly assigned during an intervention, the yield impact is likely to be influenced both by unobservable and observable heterogeneity, which leads to invalid estimation. Thus, we adopted procedures of a matching method based on the inverse probability weighted regression adjusted (IPWRA) technique, as applied by various impact evaluation studies [26–29].

In IPWRA application, we understand that it can only address self-selection bias due to observable variables, but not estimation bias due to unobservable variables, such as land quality and farmer capacity, which are common omitted variables in agricultural productivity studies. Nevertheless, the instrumental variable method’s implementation, such as endogenous switching regression as an alternative approach, faces minimal data problems to be feasible, while disentangling the ATDC program’s effects against others remain important in this paper. The farmer’s distance to the ATDC is an important factor determining whether the farmer participates in the training program or not, which means that the instrumental variables’ correlation condition is satisfied. Since the location where the ATDC was constructed is not affected by the individual characteristics, the distance to the ATDC does not affect the farmer’s productivity through any other channel than farmer training participation, satisfying the exogeneity condition of the instrumental variable. However, the distance to different trainings, particularly in farmers who participated in only other programs, is missing in our data. Thus, it may be feasible to use the distance to the ATDC from the farmer as an instrumental variable for whether or not to participate in the ATDC project, but not in other non-ATDC projects. As such, this analysis relies on the IPWRA matching method.

The treated and untreated samples are matched to estimate the average difference between outcome yields by observable characteristics in the matching approach. Here, the IPWRA implicitly compares every unit to every other, while placing higher weights on observations with a similar likelihood of being treated or untreated, and lower weights on dissimilar observations [28]. On the other hand, we have assumed that households who participated in the ATDC program faced the binary choices (1 = adopt improved rice cultivation practices that improve farm yield, 0 = otherwise). However, the decision an
individual household takes depends on certain factor/characteristic/technology attributes. Thus, reconstructing the valid counterfactuals is essential for determining the unbiased causal effects of the training program. The selected households for comparison should have the same characteristics, apart from participation in the ATDC training program, so that observed rice yield differences may be estimated as the yield impact of ATDC, not otherwise.

The advantage of the IPWRA model facilitates the estimation of yield outcome for each farmer twice. First, from the perspective of the weighted probability of being treated, second, from the weighted probability of being in the untreated group. After that, the average yield for treated and untreated households is calculated as the difference between the two averages. On the other hand, IPWRA is chosen for this study because it estimates unbiased treatment effects, even when we experience confounding effects, but it also provides a consistent estimator in the presence of misspecification in the treatment or outcome model, but not both [29–31]. The double-robust property of the IPWRA estimator ensures consistent results as the method allows the outcome and the treatment model to account for misspecification in the estimation of average treatment effect for the treated (ATT).

In IPWRA, the ATT is estimated following the two steps: using linear regression and probit regression [29,32]. A probit model predicts the participation of households in the ATDC training program, and linear regression estimates the effects of covariates on yield per acre of the individual household. Under the assumption that the outcome model is in linear regression function: 

\[ Y_i = \beta_i + \alpha_i x_i + \epsilon_i \] 

for \( i = [0,1] \) and propensity score: \( P(x; \gamma) \). The IPWRA necessitates all covariates that affect training participation to be specified in the treatment model, while covariates that affect the rice yield are also specified in the outcome model, for both treated households and untreated households. In our analysis, the households and farms covariates were used, but also, we added extension and technology adoption variables in outcome equations to estimates their effects between treated and control groups. Since beneficiaries were not randomly selected during ATDC intervention, IPWRA resolve the problem by weighting regressions where the weights are derived from inverse propensity score [28]. In the first step, the propensity score estimated as \( P(x; \gamma) \) using probit regression, and followed by linear regression to estimate \( (\beta_\omega, \alpha_\omega) \) and \( (\beta_\iota, \alpha_\iota) \) using inverse probability weighted least square as given below:

\[
\begin{align*}
\min_{\beta_\iota, \alpha_\iota} \sum_i^n Y_i - \beta_\iota + \alpha_\iota x_i / P(x, \gamma) & \text{ if } T_i = 0 \text{ (Outcome model for untreated households)} \quad (1) \\
\min_{\beta_\omega, \alpha_\omega} \sum_i^n Y_i - \beta_\omega + \alpha_\omega x_i / P(x, \gamma) & \text{ if } T_i = 1 \text{ (Outcome model for treated households)} \quad (2)
\end{align*}
\]

The estimator of ATT is the difference of Equations (1) and (2) as shown in Equation (3)

\[
ATT = \frac{1}{N_w} \sum_i^n ((\hat{\beta}_i - \hat{\beta}_\omega) - (\hat{\alpha}_i - \hat{\alpha}_\omega)x_i)
\]

where: \( (\hat{\beta}_1, \hat{\alpha}_1) \) and \( (\hat{\beta}_\omega, \hat{\alpha}_\omega) \) are estimated inverse probability-weighted parameters for treated households and untreated households, respectively. \( (N_w) \) stands for the total number of treated households.

2.3. Study Data

The data used in this study were collected from October to December 2019 from the household survey in the Mvomero district of the Morogoro region of Tanzania. Rice and maize are the main crops grown in this area. The study took place in two stages. First, a preliminary survey was conducted to understanding the rice production characteristics and training conditions in the study area. Consultations were conducted with different
stakeholders, including agricultural officials from Mvomero district, extension officers, and workers working directly with farmers from ATDC and TARI-Cholima.

We began by including all five villages that benefited from ATDC training programs from 2011 to 2019 to collect village preliminary information. The preliminary findings were used to shortlist 28 villages out of 125 villages. The nine untreated villages were randomly selected, by which four untreated villages are close to treated villages while the other five untreated villages are far away from the treated villages. Treated villages were not randomly selected; instead, we include all villages by which the ATDC rice-training program was implemented. This study classified treated villages as any village in the ATDC training program, while untreated villages are vice versa. In the treated village, about 40 treated rice farmers (participated in ATDC’s program) and 20 untreated farmers (did not participate in ATDC’s program) were randomly sampled from village farm household information, while in untreated villages, 30 rice farmers were randomly selected. Finally, we end up surveying 469 households from 14 villages using structured questionnaires.

The data were collected from rice farm households through face-to-face interviews by our trained enumerators, familiar with rice farming systems and who speak a local language. The study covered various information include household characteristics, rice cultivation practices, rice farm characteristics, and agricultural training information.

3. Empirical Results

3.1. Farmers Participation in Training Programs

From our data, it was revealed that rice farmers in the study area had undertaken various rice farming training programs between 2011 and 2019, as shown in Figure 1. However, in 2011, 2013, 2014, and 2016, farmers participated more in the ATDC training program, followed by other programs. In 2017–2019, most farmers were more involved in the Ripoma/Helvetas project, with participation in ATDC training decreasing in 2019 due to a lack of operating funds. Thus, our study has considered that various projects have been in place in the study area. Therefore, to fulfill the purpose of this study, we classified our analysis into four groups: (1) farmers who attended the ATDC training program only (here after refer as ATDC only/ATDC), (2) farmers who participated in all other training programs that excluded ATDC (here after refer as other only/non-ATDC/Other), (3) farmers who participated in both training programs, that is ATDC and non-ATDC (here after refer as ATDC and Other), and (4) farmers who did not attend any agricultural training programs (here after refer as non-trained/control). The distribution of the sample, according to these groups, indicates that 70% of the sample population (ATDC only (7%), ATDC and Other (21%), and Other only (42%)) had at least attended agricultural training, while 30% did not attend any agricultural training program. Information about the distribution of farmers in different training programs in treated and non-treated villages is available in Appendix Table A1, which indicates that about 27.3% of farmers in our sample population attended the ATDC training program in treated villages. In comparison, 72.7% did not attend the ATDC program in treated villages, while 45.4% of farmers from our sample population were drawn from non-treated villages where the ATDC program was not implemented.
3.2. Rice Farming Households Characteristics

The characteristics of the surveyed households are presented in Table 1. Results of summary statistics were tested whether there was a significant difference between the pair of means between trained farmers and non-trained/control farmers. Data indicate that the farmers groups that participated in the training programs (ATDC only, ATDC and Other, Other only, all trained) are comparable against non-trained households, mainly in terms of household and farm characteristics. However, there are significant differences in the association memberships of farming households, access to credit, farm sizes, distance from farm to agro-dealers, distance from household to ATDC, and extension and adoption characteristics.

### Table 1. Characteristics of surveyed households.

| Characteristics                                      | Mean Trained Farmers | Mean Non-trained |
|------------------------------------------------------|----------------------|------------------|
|                                                      | All Trained | ATDC | ATDC and Other | Other |                |
| Household size                                       | 4.810      | 5.313 | 5.122          | 4.574 | 4.711          |
| Rice experience of household head (year)             | 16.067     | 19.094| 16.980         | 15.122| 15.585         |
| Rice experience of spouse (year)                     | 13.947     | 16.208| 15.361         | 12.965| 13.018         |
| Spouse education (year)                              | 7.076      | 6.875 | 7.143          | 7.076 | 6.754          |
| Household head education (year)                      | 7.410      | 6.688 | 7.347          | 7.558 | 7.465          |
| Age of spouse (year)                                 | 40.099     | 39.200| 43.016         | 38.979| 39.698         |
| Age of household head (year)                         | 47.171     | 50.906| 48.694         | 45.807| 47.099         |
| Association membership (1 = yes)                     | 0.700 ** ** | 0.594 | 0.745 ** **    | 0.695 ** | 0.401         |
| Access to credit (1 = yes)                           | 0.471 ** ** | 0.281 | 0.510 ** **    | 0.482 ** | 0.275         |
| From household to ATDC (distance in km)              | 19.559 ** ** | 13.000** ** | 13.311 ** ** | 23.732 | 24.761         |
|                                                      |           |      |                |       |                |
| Farm characteristics                                 |           |      |                |       |                |
| Average acres cultivated rice in 2019               | 3.295      | 4.992 | 3.525          | 2.905 | 3.889          |
| Cultivated rice land (acre) in 2019 (direct seedling)| 1.818 *   | 2.734 | 1.561          | 1.797 | 2.829          |
Cultivated rice land (acre) in 2019 (transplanting) 1.471 * 2.258 ** 1.944 ** 1.108 1.060
Share of transplanting (acre) in 2019 0.487 * 0.479 0.544 * 0.460 0.405
Access to water for irrigation (1 = yes) 0.609 0.594 0.561 0.635 0.500
Share of Irrigated rice farm (acres) 0.378 0.323 0.403 0.374 0.325
Irrigated rice farm (acres) 1.295 1.758 1.709 * 1.014 0.990
Non-irrigated rice farm (acres) 2.087 * 3.563 1.875 1.953 3.039
Total own land (acres) 6.152 10.916 * 6.148 5.380 6.029
Paddy field own (acres) 2.689 4.328 2.977 2.280 3.234
From farm to agro-dealer (distance in km) 3.595 * 4.344 3.064 3.737 4.432

| Extension and Adoption Characteristics |
|---------------------------------------|
| Access to farm inputs (1 = yes)       |
| 0.884 *** 0.906 ** 0.878 *** 0.883 *** 0.704 |
| Agricultural advice in right time (1 = yes) |
| 0.832 *** 0.844 *** 0.857 *** 0.817 *** 0.549 |
| Access to any extension advice (1 = yes) |
| 0.878 *** 0.813 0.888 *** 0.883 *** 0.641 |
| Use water in seed selection (1 = yes) |
| 0.676 *** 0.625 0.694 *** 0.675 *** 0.423 |
| Seed pre-germination (1 = yes)        |
| 0.688 *** 0.625 0.684 *** 0.701 *** 0.465 |
| Use of seedling bed (1 = yes)         |
| 0.740 *** 0.688 0.735 *** 0.751 *** 0.542 |
| Land hallowing and levelling (1 = yes) |
| 0.810 *** 0.875 ** 0.816 *** 0.797 *** 0.613 |
| Transplanting by standardized spacing (1 = yes) |
| 0.654 *** 0.688 0.612 0.670 *** 0.465 |
| Agrochemical usage (frequency)        |
| 1.454 1.393 1.337 1.526 1.323 |
| Base fertilizer application (1 = yes)  |
| 0.364 *** 0.406 ** 0.398 *** 0.340 *** 0.162 |
| Topdressing fertilizer application (1 = yes) |
| 0.657 *** 0.656 0.663 ** 0.655 * 0.500 |
| Rice yield (kg/acre)                  |
| 1337.372 ** 1405.382 1387.540 1301.368 1088.851 |
| Participation (N = 469)               |
| 0.697 0.069 0.208 0.420 0.303 |

Note: Bonferroni multiple-comparison test *** p < 0.01, ** p < 0.05, * p < 0.1.

Household characteristics indicate no significant mean differences between farmers who attended ATDC only training and non-trained farmers. The results suggest that these two groups have similar characteristics in terms of household size, rice-farming experiences, years of education, age, association membership, and credit access. With the mean of all trained farmers, those who participated in both projects (ATDC and Other), and Other only, the association membership, and access to credit are significantly different from a non-trained group. It suggests that households who participated in non-ATDC programs (ATDC and Other, Other only) had much higher access to credit and affiliation membership in farming-based organization than those of non-trained households and ATDC only. Likewise, a mean distance from farmer households to ATDC was significantly smaller in those who participated in the ATDC program (ATDC only, and ATDC and Other), indicating they lived near ATDC.

In rice farming characteristics, there was no significant mean difference in acres of cultivated rice in 2019 among training groups. However, the share of transplanting acres was significantly higher in families participating in all training programs, particularly in ATDC and Other. The direct-seedling planted acres (broadcasting method) in the average of all trained households was significantly lower than non-trained families, with no significant difference within each trained group (ATDC only, ATDC and Other, and Other only). The mean transplanted acres were significantly high in all trained households, especially those who attended ATDC training programs (ATDC only, ATDC and Other), while the differences were not observed between other only and non-trained households. On the other hand, households who participated in ATDC and non-ATDC training (ATDC and Other) had a significantly larger size of irrigated farms than non-trained families, but the share differences of irrigated farm acres were not significant among training groups.

In contrast, Table 1 shows the mean differences of irrigation farms between the trained and non-trained households are insignificant with ATDC only, Other only, and
the mean of all trained families. Among household groups, the access to water for irrigation is insignificantly different, implying that all farmers in irrigation areas have equal access to water for irrigation. However, characteristics of farming and training of surveyed households, based on access to water for irrigation (see Appendix A Table A2), suggest that farmers with access to water for irrigation have significantly high mean irrigation farms than others. These farmers with significant mean irrigation farms in Appendix A Table A2 probably imply their access to well-established irrigation schemes, in which water availability is guaranteed because irrigation facilities are well furnished. Nevertheless, Table 1 presents that the farm size of non-irrigated rice in all trained households is smaller than a non-trained group; however, the difference is not significant among groups (ATDC only, ATDC and Other, Other only). Moreover, there are no significant differences between trained and non-trained households in terms of their land allocated in paddy production rather than in terms of total farmland owned by a farmer, where the mean difference is more significant for households that attended only ATDC training. In the case of average distances from farm to agro-dealers, the trained farmers are closer to agro-dealers than non-trained farmers; however, those differences are not significant among trained groups.

Concerning extension and adoption behavior, our data indicate significant differences between the trained and non-trained groups except in the frequency of applying agrochemicals. Access to farm inputs and agricultural advice at the right time of needs is more significant in trained households than non-trained households. The mean difference is not significant between farmers who participated only in ATDC training and non-trained groups in terms of accessing any extension advice, water practice in seed selection, seed pre-germination, use of seedling beds, and standardized transplanting. However, a considerable difference was observed in farmers who participated in both programs (ATDC and Other). On the other hand, the adoption of land hallowing and leveling, and base fertilizer application was more significant among trained households, including those who attended ATDC programs (ATDC only, ATDC and Other); topdressing fertilizer application was more substantial in those farmers who attended ATDC and Other. Moreover, the average yield of rice farmers who participated in the training (ATDC only, ATDC and Other, Other only) was higher than non-trained households, but not significantly different. Still, a significant mean yield difference is observed between trained farmers and non-trained farmers, suggesting that the trained households gained more yield than non-trained households.

In general, Table 1 indicates that training programs (includes ATDC) work because farmers use more technology/practices as suggested and obtained a high yield (check the third section of Table 1). On the other hand, the farmers who participated in training programs are like those who did not (Section 1), and their farms are not very different from those who did not participate in the training program (Section 2). Therefore, Table 1 may suggest that ATDC contributed to productivity growth, such as other training programs, and there are no vast differences between ATDC/other training programs.

3.3. Participation of Smallholder Farmers in Agricultural Training Programs

Table 2 presents farmers’ participation results in agricultural training programs. The results show that the farmers’ participation in the training program is likely to be influenced significantly by factors, such as education years of the household head, sex, size of farmland owned by farmers, distance from household to the training center (ATDC), association membership, access to extension advice, credit, and irrigation farm.
Table 2. Participation model results of inverse probability weighted regression adjusted (IPWRA) analysis.

| Variables                                  | ATDC   | ATDC and Other | Other  | All    |
|--------------------------------------------|--------|----------------|--------|--------|
| Household size                             | 0.0816 | 0.0636         | -0.0257| 0.0160 |
|                                            | (0.0661) | (0.0607)       | (0.0453) | (0.0401) |
| Household head education (year)            | -0.1360** | -0.0090       | 0.0041 | -0.0121 |
|                                            | (0.0565) | (0.0365)       | (0.0311) | (0.0274) |
| Rice experience of household head (year)   | 0.0112 | 0.0006         | -0.0030| -0.0032 |
|                                            | (0.0116) | (0.0101)       | (0.0071) | (0.0064) |
| Sex of household head (1 = male)           | -0.5130| -0.8290**      | -0.5650*** | -0.6470*** |
|                                            | (0.3460) | (0.2250)       | (0.1870) | (0.1610) |
| From farm to agro-dealer (distance in km)  | 0.0063 | -0.0051        | -0.0150| -0.0133 |
|                                            | (0.0204) | (0.0241)       | (0.0128) | (0.0123) |
| From household to ATDC (distance in km)    | -0.0355*** | -0.0409*** |        |        |
|                                            | (0.0137) | (0.0076)       |        |        |
| Access to farm inputs (1 = yes)            | 0.2490 | 0.1240         | 0.3050 | 0.2860 |
|                                            | (0.4100) | (0.2770)       | (0.2160) | (0.1840) |
| Access to any extension advice (1 = yes)   | 0.7070** | 0.8520***      | 0.5930*** | 0.6050*** |
|                                            | (0.3140) | (0.2870)       | (0.1900) | (0.1660) |
| Agricultural advice in right time (1 = yes) | 0.9010*** | 0.7630***      | 0.3850*  | 0.4840*** |
|                                            | (0.3460) | (0.2610)       | (0.1970) | (0.1680) |
| Association membership (1 = yes)           | 0.1380 | 0.6260**       | 0.5050*** | 0.5020*** |
|                                            | (0.3650) | (0.2630)       | (0.1870) | (0.1630) |
| Access to credit (1 = yes)                 | -0.5980*  | 0.1060         | 0.1940 | 0.0654 |
|                                            | (0.3550) | (0.2500)       | (0.1840) | (0.1620) |
| Access to water for irrigation (1 = yes)    | 0.0950 | -0.3190        | 0.2920 | 0.0299 |
|                                            | (0.3330) | (0.2350)       | (0.1920) | (0.1620) |
| Irrigated rice farm (acres)                | 0.0004 | -0.0330        | -0.1210** | -0.0158 |
|                                            | (0.0867) | (0.0513)       | (0.0611) | (0.0391) |
| Non-irrigated rice farm (acres)            | 0.0056 | -0.1140*       | -0.0090 | -0.0215 |
|                                            | (0.0439) | (0.0627)       | (0.0318) | (0.0296) |
| Total own land (acres)                     | 0.0263** | 0.0254         | 0.0264*  | 0.0202 |
|                                            | (0.0113) | (0.0280)       | (0.0138) | (0.0130) |
| Paddy field own (acres)                    | -0.0343| 0.0189         | -0.0423 | -0.0147 |
|                                            | (0.0479) | (0.0439)       | (0.0312) | (0.0310) |
| Constant                                  | -0.9170 | -0.5870        | -0.5540 | -0.2630 |
|                                            | (0.6830) | (0.5620)       | (0.4120) | (0.3640) |
| Observations                              | 174    | 238            | 341     | 469    |

Note: *** p < 0.01, ** p < 0.05, * p < 0.1, Standard errors in parentheses.

The results indicate that access to any extension advice and timely access to agricultural advice would increase participation by more than half in the ATDC program, which suggests that a closer relationship between farmers and local extension is essential for the success of the agricultural program. The access to any extension advice would increase farmers’ participation in ATDC only program by 70.7% and 85.2% in the ATDC and Other program, while other only programs would rise to 59.3%, which would make the average participation in all training programs increased by 60.5%. Likewise, the access to extension advice in the right time of needs would increase farmers’ participation by 90.1% in ATDC only program, 76.3% in ATDC and Other program, and 38.5% for the non-ATDC programs (Other only), which would count the average participation of 48.4% in all training programs implemented in the local area. On the other hand, farmers’ farms would positively influence participation in training programs, indicating that a one-acre increase in total owned land is associated with participation increase by 2.6% and 2.6% in the
ATDC only program and other only programs, respectively, implying that farmers with their lands participate more in agricultural training programs than otherwise.

Moreover, the membership of farmers in an association/group would increase participation by 62.6% in the ATDC and Other training program, while non-ATDC training programs (other only) increases by 50.5%. The result may also indicate that most non-ATDC training programs are disseminated via farmers’ association/groups; therefore, being a member would increase the chance of benefiting from these training programs. This is different from the ATDC program, where the membership factor does not significantly influence farmer participation, which means being an association member is not a matter for ATDC participation. This finding may suggest that both farmers, members, and non-members in the group/association participated in ATDC training programs; however, the membership of farmers in association significantly affects the rice yield of trained farmers in the ATDC only program positively.

Factors, such as distance from household to the training center (ATDC), the sex and education years of the household head, credit, and whether the farmer has access to irrigation farms, would significantly decrease farmers’ probability of participating in the training program. Results indicate that an increase of one kilometer from household to training center (ATDC) would reduce the likelihood of farmers participating in the ATDC only program by 3.6%, and 4.1% for those who participated in ATDC and Other, which implies that transportation to help bring farmers to the training center during training seasons would increase the farmers’ participation in the ATDC training program. On the other hand, the increase in the academic year of the household head would decrease the likelihood of training participation by 13.6% in the ATDC program, only because most farmers in the study area have relative basic education and, therefore, those with higher education are likely to engage in non-farm activities. While the sex of the household head (i.e., whether the head is male) would reduce the probability of participating in the ATDC and Other program by 82.9%, other only programs by 56.5%, and all training programs by 64.7%; it suggests that training participation favored women than men. Therefore, women have a higher likelihood of participating in agricultural training programs than men, because women comprise the majority of the labor force in the Tanzania agricultural sector [33].

The access to credit would reduce the probability of participating in ATDC only program by 59.8%, which suggests that most farmers who attended ATDC only program had limited access to credit, which negatively affected the yield of trained farmers in the ATDC only program. The remedy of access to credit would improve farmers’ participation in agricultural training programs and yield. Then again, an increase in an acre of irrigated rice farms would reduce farmers’ participation in other only programs by 12.1%, while an increase in non-irrigated rice farms would reduce farmers’ participation in ATDC and Other programs by 11.4%. These negative results have an important implication that participation in the non-ATDC program (other only) favors more farmers with non-irrigation farms because they have little access to irrigation farms; however, participation in ATDC and non-ATDC programs (ATDC and Other) favors more farmers with irrigation farms. Nevertheless, Table 2 reveals that those who participated in ATDC were not far from ATDC, while those who participated in other training programs were association members. Yet, farmers with more land, access to any extension advice, and agricultural advice at the right time were more likely to participate in ATDC and other programs.

3.4. Factors Affecting Yields among Trained and Non-Trained Smallholder Farmers

The IPWRA results in Table 3 indicate significant factors that negatively or positively influenced the mean yield outcome among trained (OME1) and non-trained smallholder farmers (OME0). Factors that negatively affected rice yield include household head education and rice farming experiences, distance from farm to agro-dealers, and access to farm input. Likewise, the membership of farmers in farming associations and farms owned by farmers influence positively the rice yield of trained farmers participating in
ATDC only programs. However, farm size allocated to rice farming influences negatively, pointing out that land resources were not optimally utilized in Mvomero, Tanzania.

Table 3. Outcome model results of IPWRA Analysis.

| Variables                                      | ATDC                   | ATDC and Other          | Other                  | All                    |
|------------------------------------------------|------------------------|-------------------------|------------------------|------------------------|
|                                                 | OME0 | OME1 | OME0 | OME1 | OME0 | OME1 | OME0 | OME0 | OME0 | OME1 |
| Household size                                 | 24.04 | 76.62 | 44.47 | −12.80 | 11.81 | −45.70 | 11.17 | −20.89 |
| Household head education (year)                | −17.04 | −2.24 | −9.79 | −13.30 | −16.61 | −44.96 * | −14.89 | −17.51 |
| Rice experience of household head (year)       | −12.43 * | −7.05 | −13.32 ** | −8.91 | −13.25 ** | 0.85 | −15.03 ** | 0.57 |
| Sex of household head (1 = male)               | 196.00 | −732.50 * | 203.90 | 360.20 *** | 176.90 | 179.00 | 234.00 | 114.30 |
| From farm to agro-dealer (distance in km)      | −11.13 | 150.50 *** | −9.47 | −21.29 | −11.59 | −40.85 *** | −8.02 | −22.36 ** |
| Access to farm inputs (1 = yes)                | (9.24) | (36.28) | (10.56) | (26.17) | (10.37) | (9.42) | (11.46) | (10.08) |
| Access to any extension advice (1 = yes)       | −8.93 | 988.70 *** | −83.50 | −886.40 *** | −75.39 | −70.55 | −131.40 | −243.10 * |
| Agricultural advice at the right time (1 = yes)| 103.10 | −241.10 | 227.80 | −202.40 | 227.10 | 180.40 | 268.90 | 164.20 |
| Association membership (1 = yes)               | −177.70 | 1386.00 *** | −278.30 | −291.50 | −219.00 | 31.29 | −228.40 | 31.62 |
| Access to credit (1 = yes)                     | 126.00 | −660.50 ** | 190.50 | 202.20 | 94.08 | 88.74 | 127.70 | −5.09 |
| Access to water for irrigation (1 = yes)       | 390.00 | −1421.00 ** | 385.70 | 780.00 *** | 374.20 | 258.20 | 347.00 | 158.90 |
| Irrigated rice farm (acres)                    | (26.70) | (599.90) | (289.00) | (251.10) | (244.20) | (212.70) | (266.10) | (193.90) |
| Non-irrigated rice farm (acres)                | 4.39 | 260.30 | 69.86 | −129.10 | 14.38 | 143.10 * | 0.24 | 137.30 * |
| Total own land(acres)                          | (128.70) | (283.20) | (147.80) | (114.40) | (134.60) | (73.58) | (134.90) | (78.15) |
| Paddy field own (acres)                        | −199.20 *** | −138.90 | −198.80 *** | −32.77 | −195.30 *** | 22.75 | −190.70 *** | −36.65 |
| Cultivated rice land (acre) in 2019 (direct seedling) | (36.62) | (200.60) | (38.54) | (75.87) | (34.08) | (132.10) | (32.11) | (78.71) |
| Cultivated rice land (acre) in 2019 (transplanting) | (26.94) | (65.30) | (32.40) | (32.95) | (28.05) | (33.39) | (25.83) | (20.72) |
| Use water in seed selection (1 = yes)          | −109.70 | −186.80 | −305.70 | 381.40 ** | −198.20 | 50.94 | −196.50 | 111.10 |
| Seed pre-germination (1 = yes)                 | 277.60 | 956.60 ** | 450.20 | 233.10 | 151.00 | 232.20 | 270.70 | 246.30 |
| Use of seeding bed (1 = yes)                   | 347.50 | 388.10 | 385.20 | −406.30 * | 367.30 | 124.70 | 283.40 | 195.20 |
| Land hallow and leveling (1 = yes)             | −65.13 | −80.44 | −17.79 | 103.40 | −32.23 | 421.70 *** | −17.35 | 283.20 ** |
| Transplanting in standardized spacing (1 = yes)| 82.70 | −134.00 | 200.70 | 320.50 * | 90.77 | −252.30 | 85.91 | −170.80 |
Agrochemical usage (frequency)  
(237.40)  (310.80)  (248.90)  (180.50)  (254.50)  (218.40)  (266.50)  (155.50)  
40.01  12.91  76.94  –34.01  110.10  60.03  100.40  11.62  
(77.15)  (137.80)  (77.26)  (86.26)  (73.56)  (65.31)  (76.78)  (53.98)  
Base fertilizer application (1 = yes)  
182.40  793.00 ***  308.30  397.60 **  202.10  284.10 *  273.20  299.40 **  
(240.30)  (254.90)  (250.00)  (159.60)  (217.10)  (151.40)  (239.30)  (131.10)  
Topdressing fertilizer application (1 = yes)  
134.60  187.70  65.10  211.40  167.80  4.01  197.70  182.30  
(242.20)  (463.50)  (290.10)  (245.80)  (235.20)  (164.40)  (264.80)  (156.10)  
Constant  
812.20 **  814.20  676.30 *  1988.00 ***  900.80 ***  884.00 **  879.10 ***  764.30 **  
(343.30)  (652.80)  (361.20)  (389.20)  (312.60)  (428.70)  (335.10)  (305.70)  
Program (ATE)—trained vs. non-trained (Kg/acre)  
–150.60  254.70 **  –40.15  39.41  
(290.00)  (115.80)  (96.95)  (290.00)  
Potential household mean yield (Kg/acre)  
1077.00 ***  1157.00 ***  1204.00 ***  1203.00 ***  
(77.24)  (85.40)  (74.59)  (80.71)  
Observations  
174  174  238  238  341  341  469  469  

Note: *** p < 0.01, ** p < 0.05, * p < 0.1, Standard errors in parentheses.

The increase of household head education years seems to affect the rice yield of trained farmers from other programs negatively. This result suggest that household head engagement in rice farming jobs would shift to non-farm because farmers with high education are more likely to engage in non-farm activities [34].

The sex of the household head, if male, affects negative the yield of participated farmers in the ATDC only program, while favoring the yield of farmers participating in both ATDC and Other program. It indicates that the rice yield of female-headed households who participated in the ATDC training program was slightly higher than in male-headed households, suggesting that women can perform better when accessing the training program. However, access to productive resources is more critical, especially in the Tanzania context, where women are more constrained in adopting and benefiting from irrigation technologies compared to men [35]. This supports the significant coefficient of “sex of the household head” in the ATDC and Other, as participants in this program have a substantial share of irrigation farm (see Table 1). The FAO suggests that women are just as efficient as men and would achieve the same yields if they had equal access to productive resources and services; however, the limited access to resources may decrease women productivity, up to 30% [36].

Rice farming experience of the household head significantly affected non-trained farmers in either training program, which indicates that a one-year increase would reduce productivity. This finding is inconsistent with other studies [37,38], which noted that farming experience increases farmer technical efficiency and adoption of technology and, therefore, improves farm yield. However, another study found that the awareness of rice farming management practices was low, even among farmers with more farming experiences; thus, they continued with conventional rice production that had lower yield return [39]. In this case, our study’s findings may indicate that farming experience alone is not enough to guarantee smallholder farmers’ production efficiency that can increase significant productivity. Therefore, administering more agricultural training programs to instill the right skills and knowledge are crucial for enhancing farming productivity.

The distance from farms to agro-dealers negatively influenced the rice yield of farmers who participated in non-ATDC (other only) and all projects in general, which suggests an increase in distance from farm to the agro-dealer would challenge trained farmers from purchasing recommended farm inputs from agro-suppliers. However, distance from farm to agro-dealers would not averse farmers participated in ATDC only program; still, access to farm input would reduce the yield of trained farmers, suggesting that farm inputs may not be accessible when needed at the right time of production, even if farmers are willing to purchase. Thus, improving the accessibility of farm inputs at the right time and the distribution of agro-dealers close to farms may play a significant role in facilitating the use of improved farm inputs that may improve farm yields.
While supply chains can affect agricultural inputs accessibility, which may decrease adoption of technology and rice yields, improving the availability of farm inputs, in terms of distribution, transaction cost, and credit, may increase the possibility of attaining potential yield. On the other hand, access to farm input may still affect yield negatively if farmers face difficult access in acquiring inputs or inputs that are not delivered at the right time due to poor infrastructure. This may complement the access to extension advice that encourages farmers to acquire the right farm inputs, especially when the required inputs in farm production are not clear to farmers. Following our results, we noted a positive relation of access to any extension advice on rice yield of households in ATDC only programs; however, the negative results were also noted to those who participated in both ATDC and Other programs. The finding may likely suggest that extension advice from many sources may likely mislead farmers and ultimately reduce their productivity. Thus, extension advice and training should be more specific to farmers in order to guide them to the best decision in inputs allocation and utilization. In contrast, other researchers [40–43] have also noted the benefit of extension advice and training on adopting improved technology, which may increase farmers’ productivity.

Access to irrigated fields has significantly increased the rice yields of farmers trained in non-ATDC (other only) programs and all training programs in general. Our results suggest that there is a positive relationship between irrigated fields and rice yields. However, rice cultivation in non-irrigated areas has significantly reduced the potential for high yields for trained and untrained farmers in ATDC and non-ATDC programs. Farming in non-irrigation areas means rainfed farming, whereby unpredictable rainfall usually affects yield outcome. Similarly, limited access to water for irrigation has reduced yields for some farmers who participated in ATDC programs only, while access to irrigation water increases the rice yields of farmers trained at ATDC and Other. These results may indicate that rice farming in non-irrigated farms, where water is not assured to approve better rice farming practices, places farmers at risk of adopting the technology.

When the farming environment does not guarantee better results, if the farmer invests in the best farming techniques, ultimately, trained and untrained farmers will continue to use traditional practices, even after training programs, as evidenced in our results. A positive relationship between yield and field size cultivated through direct seed, which is a traditional practice, has been revealed among participants of the non-ATDC programs. It shows that some farmers cultivate in non-irrigated areas (so not-transplanted), which may suggest that technology adoption is sometimes constrained by factors beyond the farmers’ control, which needs further improvements for training to be practical.

Moreover, You [44] has noted the technology bias in agricultural research and development (R&D) towards irrigated rice because most modern rice varieties are bred under the irrigated conditions so that the rice seed would perform better with irrigation. Nevertheless, the adoption of improved seed, fertilizer, and other improved technology in irrigation farms will not work well independently. These technologies need to complement each other because their combined effects are more than the sum of their individual effects. Likewise, the benefit of access to an irrigation farm is like drought insurance, because with irrigation, the farmer will be willing to invest in fertilizer and seed, and other technologies, without fear of losing these pre-harvest investments in case of a drought. The argument is also supported by our data, which indicate that the adoption of agricultural technologies and rice yields are more significant among farmers with access to water for irrigation than otherwise (see Appendix Table A2). On the other hand, among farmers with limited access to water for irrigation, there is no significant difference in yield between trained and non-trained farmers, even if technology adoption is evidenced among trained farmers. These results can provide micro-empirical evidence with important literature, such as the theory of induced innovation and adaptive investment in technology transfer.

3.5. Impact of Training Programs on Technology Adoption and Yield of Smallholder Farmer
Results in Table 3 show that trained farmers groups adopted some technology, which indicates that agricultural training programs may influence farm technology adoption and improve smallholder farmers’ yield. For instance, the practice of seed selection by using water significantly increased adopters’ rice yield by 381 kg/acre than those who did not adopt among trained farmers in ATDC and Other programs, though it is insignificant for ATDC only and Other only programs. This practice is the first crucial stage determining the seed quality and so germination of the plant and productivity. It ensures a better seed, which may result in a healthier seedling. Thus, the adoption of a seed selection procedure by using water facilitate farmers to plant only the highest quality rice seed, which leads to rice yield improvement. The finding is in line with International Rice Research Institute (IRRI) [45], which noted that the selection of good quality seeds might improve germination by more than 80% and increase the rice yield by 5–20%.

Seed pre-germination practice that improves seed establishment before sowing increased the yield of trained farmers in the ATDC only program. It was revealed that the yield of adopters significantly increased by 957 Kg/acre than non-adopters. This finding supports other studies that have revealed the positive impact of pre germination practice on yield, such as Tilahun-Tadesse et al. [46], who found planting pre-germinated rice seeds may increase yield advantage up to 58%, while Farooq et al. [47] noted 11–24% yield advantage.

On the other hand, training programs also impacted the adoption of basal fertilizer. Our research findings revealed that adopters of basal fertilizer among trainees groups improved the yield significantly by 793 kg/acre (ATDC only), 398 kg/acre (ATDC and Other), 284 kg/acre (other only), and 299 kg/acre (all training programs in general), which support the study of [12], who noted yield increases of 563 kg/acre when farmers applied basal fertilizer.

In comparison with farmers who participated in the ATDC and Other program, the non-adopters of seedling bed practices among non-participants lose significantly about 406 kg/acre, while those transplanting following specified spacing and row gained a yield increase by 321 kg/acre. The land hallowing and leveling practices improved the yield by 422 kg/acre and 283 kg/acre, respectively, among adopters in non-ATDC projects and all training in general.

Above all, this study revealed that both the ATDC training program and non-ATDC programs facilitated the adoption of improved rice practices, and, therefore, improved the yield of smallholder farmers in the study area. The result might provide a clue to the inconsistent finding of the impact of agricultural training programs in Africa. However, the average treatment effect on treated, which suggests the average yield impact of the program on beneficiaries, is neither significant for ATDC only beneficiaries nor non-ATDC only beneficiaries. Nevertheless, the impact training is significant on farmers who participated in both programs (ATDC and Other), suggesting that training has significantly improved yield by 255 kg/acre.

This study indicates that training increases productivity, especially in the context of irrigation, because farmers who participated in both ATDC and Other had the advantage of access to irrigation farms and water for irrigation than other farmers groups (see Table 1). Our further analysis revealed that trained and non-trained farmers with access to water for irrigation adopted technology significantly, and yield was more than double than their counterparts. Their yield effect estimation (average treatment effects—ATE) is significantly higher (1131 kg/acre and 940 kg/acre, respectively) than the comparison group (non-trained farmers without access to water) (see Appendix Table A2). On the other hand, the yield difference between trained and non-trained farmers is insignificant in non-irrigated plots. In contrast, the ATE estimation on yield is a significant 862 kg/acre between “trained and irrigated vs. trained and non-irrigated”, while in “non-trained and irrigated vs. trained and non-irrigated” it is 751 kg/acre.

Moreover, results of ATDC only and non-ATDC only beneficiaries suggest that a participation training program does not always improve the yield of smallholder farmers
in developing countries, where farming infrastructure are neither perfect nor the accessibility of water for irrigation. Therefore, agricultural training programs should not be considered the only influencing factor for accelerating smallholder farmers’ productivity. The influence of supportive factors for enhancing the adoption of agricultural technology and yield improvements (such as irrigation facilities, agricultural credit, farm inputs availability and accessibility, and access to agricultural advice at the right time) should be critically analyzed as it will ensure the best results of agricultural training programs. On the other hand, our analysis revealed a positive impact of agricultural training programs on irrigated plots, but not rain-fed plots. This finding might provide an answer to why a positive impact had been found in some previous studies [5,12,48] and not in other previous studies [49–51].

3.6. The Spillover Effect of Training Programs

The agricultural training programs may benefit non-training participants through the spillover effect of the training program, resulting from social interaction with treated farmers. The flow of technology information from person to person within the community networks (such as farmers’ groups/associations) may improve the adoption of agricultural technology practices and yield for non-trained participants. Therefore, failure to recognize the spillover effect in our analysis may underestimate the effectiveness of a training program on technology adoption and yield because its effect on untreated will go unmeasured [52]. In this case, we decided to extrapolate whether non-participants in the agricultural training programs were indirectly affected by training intervention through farmers’ interaction with treated farmers. Thus, we tested the role of farmers’ social networks (farmers with membership in any group/association vs. those without membership) in facilitating the spread of technology adoption from trained to non-trained farmers.

Our data suggest that being a member of any farmers’ group increases the possibility of access to agricultural training opportunities up to 49%, while not being a member reduces the accessibility by 28%. The mean adoption of technology among training participants and non-participants is indicated in Appendix A Table A3 based on farmers’ group membership status. Our results show no significant differences in technology adoption between trained and non-trained farmers who are members of groups, except in base fertilizer application (trained vs. non-trained group member), which suggests the evidence of spillover effect of a training program on technology disseminated to trained farmers. The mean yields of trained farmers are higher than non-trained, although the difference is not significant. This suggests non-trained farmers also adopted technology through social interactions by observing and imitating trained farmers. In contrast, the significant mean difference in technology adoption and yield between trained in farmers groups against non-trained in non-farmers groups may suggest a lack of spillover effect between them (trained group member vs. non-trained who are not group member). The low adoption of technology is noted significantly among non-trained farmers who are not group members, which suggests that farmers belong to farmers groups, adopting more technologies that result in higher yields than other farmers.

Regarding the impact of training programs, by considering farmers’ group membership, the ATEs are insignificant. However, it indicates the training programs would positively affect the yield of non-trained farmers who are not members of farmers groups by 144 kg/acre, than trained farmers from farming groups. The ATE analysis between trained and non-trained with the membership of farming groups indicates the impact of the training program, on non-trained in farmers groups, is 252 kg/acre, which is insignificant. These insignificant ATE results may suggest that the impact of agricultural training programs was not significantly reflected in the yields among those who did not benefit from such programs. However, the indirect effects of training programs may exist on technology adoption. Nevertheless, the ATE of non-trained who are in farming groups (252 kg/acre) is higher than trained who are not in farming groups (104 kg/acre), suggesting that the training programs have more effective results when disseminated via farming
group members, because even indirect beneficiaries within the farmers groups can benefit more than direct beneficiaries outside farmers group. Inline, group membership can reduce the perceived risks to invest in improved technology because, within the group, knowledge and support are shared when applying new technology, which may indirectly benefit other farmers within the social network. Therefore, consideration of farmers’ group members’ participation during training dissemination is important. However, the ATE of group membership (group member vs. non-group member) is not significant, but its positive coefficient may indicate the positive synergy effect of the group membership.

4. Conclusions and Policy Implication

Understanding properly the impact of agricultural training programs on smallholder farmers’ productivity is crucial for ensuring food security and poverty reduction in Africa. The Agricultural Technology Demonstration Center (ATDC) program is a Chinese technology transfer initiative established through a China–Africa agricultural cooperation (2009–2013) to support agricultural growth and food security in Africa through training and demonstration programs. With massive investments in ATDC through the China–Africa cooperation, all stakeholders had high hopes for its success. Nevertheless, our results in Tanzania case study indicates that the yield improvement of training participants with no access to water for irrigation was not significant. However, the yields among trained and non-trained farmers with access to water for irrigation were significantly more than double than the comparison group (non-trained farmers without access to water), while the yield difference between trained and non-trained farmers was insignificant in non-irrigated plots. The results might provide a clue to the inconsistent findings of previous studies on the impact of agricultural training programs in Africa.

The study may hold a lesson for the architects of agricultural development programs—that training programs should not be considered as the only influencing factors for accelerating smallholder farmers’ productivity. The farming environment should be considered necessary. Rice technologies/practices that focus on non-irrigated fields should be addressed. Training that introduces new technologies/practices, such as seed varieties with higher yield, should consider the influence of supportive factors (such as irrigation facilities, agricultural credit, farm inputs availability and accessibility, and access to agricultural advice at the right time) to ensure the best results of agricultural training programs.

Additionally, the examination of social networks revealed no huge differences in technology adoption between trained and non-trained farmers who are members of groups, indicating evidence of a training program’s spillover effect. However, the impact of agricultural training programs was not significantly reflected in yields. However, the ATE coefficient in non-trained in farmers groups was still higher than trained who are not in farming groups. This suggests that training programs have more effective results when disseminated via farming group representative members, because even indirect beneficiaries within farmers groups might benefit more than direct beneficiaries who are outside the farming groups.

Above all, referring to the implementers of agricultural development programs, such as ATDC, some recommendations might apply to make intervention more effective:
- First, the training program should be disseminated in the correct production calendar to enhance practicability and usefulness (in the ATDC program, some farmers participated during rice harvesting festivals, which questions the extent of their participation in the training program and the level of empowerment) [11,22]).
- Second, the close linkage of the agricultural training program to local extension services may be essential for farmers’ participation and program effectiveness.
- Third, any agricultural program design should consider accountability and impact assessment within the program to prepare beneficiaries to become proficient and use proficiency in their field.
Our investigation noted that farmers experienced little consultation with Chinese experts—there is no formal feedback system and communication language is a challenge. We realized that there had been no rigorous monitoring and follow-up in ATDC activities to empower farmers and trace the theory of change, which may affect the program’s effectiveness. Moreover, there were no clear guidelines on how much effort should be dedicated to training or commercial activities, which might incline ATDC to focus more on business rather than capacitating farmers to improve yields. Therefore, agricultural program architects should consider improving the program design, to enhance the farming training program’s effectiveness and positively impact farmers’ yields.

Moreover, further research may be required for identifying key factors that affect technology adoption and measures to improve agricultural technology program efficiency. The cross-section data employed in this study face limitations of capturing information in time and space, which cannot completely explain the incidences throughout the program intervention. Thus, the panel data may be recommended to study the impact of agricultural training programs (e.g., ATDC). The advantage of panel data is to address the dynamic behavior response of training program interventions that allow researchers to trace the impact change over time.

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**Appendix A**

**Table A1.** A number of farmers participated in different training programs in treated and untreated villages.

|                       | In Treated Villages | Non-Treated Villages | In Non-Treated Villages |
|-----------------------|---------------------|----------------------|-------------------------|
|                       | Treated Farmers     | Non-Treated Farmers  |                         |
| ATDC                  | 128                 | 128                  | 213                     |
| FAO and IRRI          | 3                   | 4                    | 5                       |
| Ripoma/Helvetas       | 44                  | 36                   | 95                      |
| JAICA                 | 9                   | 7                    | 6                       |
| USAID/NAFAKA          | 30                  | 12                   | 21                      |
| Tanzania Agric. Research Institutes (TARI) | 25 | 7 | 27 |
| Village extension officers | 19 | 14 | 21 |
| Agricultural University/College | 7 | 1 | 16 |
| Other NGO/institution | 29                  | 21                   | 26                      |
| Total sample (N = 469)| 128                 | 128                  | 213                     |
Table A2. Characteristics of irrigation farming and training of the surveyed households.

| Characteristics                                      | Mean (Access to Water for Irrigation = 1) | Mean (Access to Water for Irrigation = 0) |
|------------------------------------------------------|------------------------------------------|------------------------------------------|
|                                                      | Trained Farmers | Non-Trained Farmers | Trained Farmers | Non-Trained Farmers/Control |
| Household characteristics                             |               |                    |               |                               |
| Household size                                        | 4.714         | 4.690              | 4.961         | 4.732                         |
| Rice experience of household head (year)              | 16.090        | 15.746             | 16.031        | 15.423                        |
| Rice experience of spouse (year)                      | 13.400        | 12.439             | 14.904        | 13.630                        |
| Spouse education (year)                               | 7.126         | 6.915              | 7.000         | 6.592                         |
| Household head education (year)                       | 7.442         | 7.817              | 7.359         | 7.113                         |
| Age of spouse (year)                                  | 39.354        | 37.712             | 41.388        | 41.754                        |
| Age of household head (year)                          | 47.362        | 45.338             | 46.875        | 48.859                        |
| Association membership (1 = yes)                      | 0.769 ***     | 0.535 ***          | 0.594 ***     | 0.268                         |
| Access to credit (1 = yes)                            | 0.487 ***     | 0.324              | 0.445 ***     | 0.225                         |
| Farm characteristics                                  |               |                    |               |                               |
| Average acres cultivated rice land in 2019           | 4.041         | 3.359              | 2.135 **      | 4.149                         |
| Cultivated rice land (acre) in 2019 (direct seeding) | 1.883 ***     | 1.489 **           | 1.740 ***     | 4.169                         |
| Cultivated rice land (acre) in 2019 (transplanting)   | 2.158 ***     | 1.870 ***          | 0.402         | 0.250                         |
| Share of transplanting (acre) in 2019                 | 0.621 ***     | 0.645 ***          | 0.278         | 0.165                         |
| Share of irrigation acres                             | 0.603 ***     | 0.597 ***          | 0.028         | 0.053                         |
| Irrigated rice farm (acres)                           | 2.108 ***     | 1.835 ***          | 0.031         | 0.144                         |
| Non-irrigated rice farm (acres)                       | 2.078 **      | 1.845 **           | 2.102 **      | 4.232                         |
| Total own land(acre)                                  | 6.619         | 4.937              | 5.426         | 7.120                         |
| Paddy field own (acres)                               | 3.318         | 2.546              | 1.713 **      | 3.923                         |
| From farm to agro-dealer (distance in km)             | 3.545 ***     | 3.042 ***          | 3.672 **      | 5.821                         |
| Extension and Adoption Characteristics                |               |                    |               |                               |
| Access to farm inputs (1 = yes)                       | 0.925 ***     | 0.817 ***          | 0.820 ***     | 0.592                         |
| Agricultural advice in right time (1 = yes)           | 0.874 ***     | 0.648 **           | 0.766 ***     | 0.451                         |
| Access to any extension advice (1 = yes)              | 0.894 ***     | 0.746 ***          | 0.852 ***     | 0.535                         |
| Use water in seed selection (1 = yes)                 | 0.869 ***     | 0.718 ***          | 0.375 ***     | 0.127                         |
| Seed pre-germination (1 = yes)                        | 0.905 ***     | 0.803 ***          | 0.352 ***     | 0.127                         |
| Use of seedling bed (1 = yes)                         | 0.980 ***     | 0.901 ***          | 0.367 ***     | 0.183                         |
| Transplanting by standardized spacing (1 = yes)       | 0.894 ***     | 0.789 ***          | 0.281 *       | 0.141                         |
| Agrochemical usage (frequency)                        | 1.618 ***     | 1.577 ***          | 0.813         | 0.732                         |
| Base fertilizer application (1 = yes)                 | 0.528 ***     | 0.296 ***          | 0.109         | 0.028                         |
| Topdressing fertilizer application (1 = yes)          | 0.910 ***     | 0.831 ***          | 0.266         | 0.169                         |
| Rice yield (kg/acre)                                  | 1718.784 ***  | 1517.547 ***       | 744.395       | 660.154                       |
| Observation                                           | 199           | 71                 | 128           | 71                            |

Average treatment effects (ATE) estimation on rice yield (kg/acre): nearest-neighbor matching (Mahalanobis)

- Trained and irrigated vs. non-trained and non-irrigated: 1131.000 *** (150.800)
- Non-trained and irrigated vs. non-trained and non-irrigated: 940.000 *** (146.200)
- Trained and non-irrigated vs. non-trained and non-irrigated: 102.400 (152.100)
- Trained and irrigated vs. non-trained and non-irrigated: 224.100 (137.800)
- Trained and irrigated vs. trained and non-irrigated: 862.400 *** (159.100)
- Non-trained and irrigated vs. trained and non-irrigated: 750.800 *** (150.800)

**Observations**: 270, 142, 199, 327

Note: Mean comparison is the Bonferroni multiple test, ATE’s standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 

Table A3. Adoption of technology and yield impact of training program among farmers groups.

| Mean Adoption of Technology Among Farmers | Trained Farmer and Group Member | Non-Trained Farmer and Group Member | Trained Farmer and Not a Group Member | Non-Trained Farmer and Not a Group Member |
|------------------------------------------|--------------------------------|-----------------------------------|------------------------------------|----------------------------------------|
| T = 1, E = 1                            | Spillover          | No Spillover                       |
| Use water in seed selection (1 = yes)   | 0.712             | 0.544                             | 0.592                              | 0.341 ***                              |
| Seed pre-germination (1 = yes)          | 0.729             | 0.596                             | 0.592 *                            | 0.376 ***                              |
| Use of seedling bed (1 = yes)           | 0.795             | 0.667                             | 0.612 ***                          | 0.459 ***                              |
| Land hallowing and levelling (1 = yes)  | 0.812             | 0.684                             | 0.806                              | 0.565 ***                              |
| Transplanting by standardized spacing (1 = yes) | 0.703 | 0.579                             | 0.541 **                           | 0.388 ***                              |
| Agrochemical usage(frequency)           | 1.389             | 1.439                             | 1.102                              | 0.965 ***                              |
| Base fertilizer application (1 = yes)   | 0.428             | 0.193 ***                         | 0.214 ***                          | 0.141 ***                              |
| Topdressing fertilizer application (1 = yes) | 0.716 | 0.596                             | 0.520 ***                          | 0.435 ***                              |
| Rice yield (kg/acre)                    | 1432.047          | 1164.396                          | 1116.141 *                         | 1038.191 **                            |
| Training participation (1 = yes)        | 0.488             | 0.209                             |                                    |                                        |
| Sample (N = 469)                        | 229               | 57                                | 98                                 | 85                                     |

Average treatment effects (ATE) estimation on rice yield (kg/acre): nearest-neighbor matching (Mahalanobis)

- Trained vs. non-trained group member: 252.300 (131.700)
- Trained group member vs. trained who are not group member: 104.100 (120.800)
- Trained group member vs. non-trained who are not group member: 143.900 (189.300)
- Group member vs. non-group member: 3,700 (96.600)

Observations: 469 286 327 314

Note: Mean comparison is the Bonferroni multiple test, ATE’s standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1. T = Training intervention (1 = received, 0 = otherwise), E = Member of farmers group (1 = have membership, 0 = otherwise).

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