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The Importance of Farm Management Training for the African Rice Green Revolution: Experimental Evidence from Rainfed Lowland Areas in Mozambique

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Abstract

There remains an unsettled question regarding the achievement of the African rice Green Revolution (GR): Must a region start from the adoption of basic farm management practices (e.g., seed selection, nursery bed set-up, field leveling, bund construction, and transplanting), many of which were already common in Asia at the time of its GR? This study evaluated a randomized controlled trial (RCT) of training in such basic practices in remote rainfed lowland areas of Mozambique. The training employed two approaches: implementing farmer field schools in demonstration plots and promoting farmer-to-farmer social learning. The intention-to-treat (ITT) effect on the yield was 447–546 kg/ha (29%–36% of the control group average yield), with statistical significance at 7%–8%, regardless of the irregular rainfall conditions. The results indicate that the adoption of basic practices alone can improve rice yield even without modern inputs such as modern varieties and inorganic fertilizer, which are not easily available in local markets in remote areas or accessible to cash-constrained farmers. We also found complementarity among the basic practices, indicating that they must be adopted as a package for effective yield improvement.

Keywords: Management training, extension systems, technology adoption, rice, Green Revolution

JEL Classification: O12, O13, O33, Q12, Q16

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Highlights

- A randomized controlled trial of rice farm management training was conducted in remote rainfed lowland areas of Mozambique.
- The intention-to-treat (ITT) effect on the yield was 447–546 kg/ha (29%–36% of the control group average yield), with statistical significance at 7%–8%.
- Yield increased when the basic practices (e.g., seed selection, nursery bed set-up, field leveling and bunding, and transplanting) were adopted as a full package, indicating complementarity.
- Yield increased without modern purchased inputs (improved varieties and inorganic fertilizer), indicating the effectiveness of management training for cash-constrained farmers in remote areas.

1. Introduction

Rice consumption in Sub-Saharan Africa (SSA) has been growing at a faster pace than local production (4.2% and 3.5% annually from 1960 to 2020, respectively) (USDA 2021). Meanwhile, SSA has lagged far behind the areas blessed with Green Revolution (GR) technologies, awaiting their African versions (Gollin et al. 2021; Evenson and Gollin 2004). Land productivity improvement or Asian-style GR should be one of the key components of their strategies to overcome these problems because the land-labor ratio in SSA has already reached a lower level than tropical Asia in the 1960s, on the eve of the Asian GR (Otsuka and Larson 2013, 2016). In addition, African GR must be realized in the rainfed area, at least in the short- or medium-term, because the proportion of area equipped with irrigation facilities remains marginal at about 3% in the region (AQUASTAT 2021).

However, a simple replication of Asia's experiences is not enough for this purpose because it has been argued that the introduction of seed-fertilizer technologies alone is not enough for SSA. Instead, SSA must start from the adoption of basic management practices such as seed selection and nursery bed setup (for quality seedlings), field leveling and bund construction (for even water distribution), straight-row transplanting (for easier crop management and weeding), timely weeding, and water management, some of which were already common in Asia at the time of its GR (Kijima 2012; Balasubramanian et al. 2007; Barker and Hardt 1985). The effective adoption of such basic practices may not be the same as that of seed-fertilizer technologies. The former needs farmers to adopt the package of practices as an integrated system and, thus, are more complicated and knowledge-intensive. Moreover, farmers must properly adopt the right way of practicing and maintaining them. This is in contrast with the adoption of modern inputs such as seed-fertilizer technologies, where the essence of technologies is embedded within the seed and fertilizer, and the benefits are realized by applying modern inputs to the field, although farmers still need to learn how to use them. This implies that the extension program for SSA must include training in basic practices, and extension systems must be effectively designed for the proper and sustained use of the learned practices.

The purpose of this study was to assess the effectiveness of training in basic rice farm management practices by means of a randomized controlled trial (RCT) of the training program provided by the Japan International Cooperation Agency (JICA) in remote rainfed lowland areas in Mozambique. Mozambique is an appropriate case because its rice productivity is still very low, about 1 t/ha on average in 2020, and the rice is mostly cultivated in rainfed lowlands (Kajisa 2015; Kajisa and Payongayong 2011). The training has three features. First, the training was a combination of a conventional approach (farmer field schools (FFS) at demonstration plots) and a contemporary approach (farmer-to-farmer extension (F2FE) through social learning). Second, the training did not provide any performance-based monetary incentives as a means of accelerating technology diffusion. Third, the training did not rely on modern inputs, such as the newly developed improved varieties and inorganic fertilizers, because these are not options for remote rainfed farmers, who are usually cash and market-access constrained.

Our study contributes to the literature in two ways. First, it adds to the body of literature on the African Green Revolution, where case studies on rainfed lowlands are relatively scarce (Gollin et al. 2021; Otsuka and Larson 2016, 2013; Evenson and Gollin 2003).[1] Our analysis revealed three key points. First, the adoption of basic practices is essential to improve rice yield for African GRs. Second, the practices must be adopted as a package, rather than individually, supporting an integrated farm management approach (Takahashi et al. 2020). Third, yield improvement is possible even without modern purchased inputs, although the potential impact is not as high as with modern inputs under irrigated conditions. This means that even remote rainfed farmers can still benefit from such training.

[1] Exceptions include studies on rainfed rice by Nakano et al. (2018a) in Tanzania, deGraft-Johnson et al. (2014) in Ghana, and Kijima et al. (2012) in Uganda.

Second, our analysis can supplement the growing body of literature on agricultural extension and technology adoption. Based on past experience, the literature on agricultural extension systems argues that conventional approaches such as training and visit (T&V) and farmer field schools (FFS) were costly and not consistently successful in Asia (Antholt 1998). Recent studies have stressed that F2FE is a more inexpensive and effective method (Fafchamps et al. 2021; Behaghel et al. 2020; Takahashi et al. 2019; Takahashi et al. 2020; BenYishay and Mobarak 2018; Nakano et al. 2018b; and Conley and Udry 2010). Our case study provides an example of a combination of conventional and recent approaches. However, disentangling these two to determine their complementary effects was not possible in our RCT setting. Moreover, emerging issues in the F2FE approach include whether monetary incentives for dissemination activities matter (Behaghel et al. 2020; Takahashi et al. 2019; Nakano et al. 2018b; BenYishay and Mobarak 2018). Our case joins the subset of the literature showing that there is effective diffusion even without monetary incentives to the farmers who teach new technologies to others.

The rest of the paper is organized as follows: Section 2 explains the study site and experimental design, and this is followed by our examination of summary statistics and the balancing test in Section 3. Section 4 presents our estimation strategies and regression results on the impact assessment of the training and identification of appropriate yield-improving practices. Finally, Section 5 concludes the paper.

2. Study Site and Experimental Design

2.1 Rice in Mozambique

The importance of rice in Mozambique has been increasing rapidly. As a result of increased urbanization and the convenience of preparing rice meals, Mozambique, like other African countries, has seen a shift in consumer preference for rice (Hossain 2006). Therefore, rice consumption in Mozambique rapidly increased by 8.9% annually from 1990 to 2020, faster than the increases in maize, 4.5%, or wheat, 6.1% (USDA 2021). In response to this increase, production grew initially at 12.1% annually from 1993 to 1998, but growth stagnated in the 2000s (Figure 1). As shown in Figure 2, the marginal growth in production is attributed to the expansion of the harvested area, rather than productivity improvements. Paddy yield has stagnated at a level lower than 1 ton per hectare. This stagnation results in a rapid increase in rice imports, as indicated by the widening gap between consumption and production (Figure 1).

Rice in Mozambique is produced mostly in the rainfed lowland ecological regions, where farmers follow traditional cultivation practices. The area equipped with irrigation facilities accounts for only 2% of the arable land in the country. Among the rainfed lowland areas, Zambézia Province, including the Zambézi River basin, is the dominant rice producing province (48% of the total rice area), followed by Nampula (14%), Sofala (12%), and Cebo Delgado (10%) (Anuário de Estatisticas Agrárias 2015; Figure 3). The project to improve rice productivity in Zambézia Province started in 2016 with financial support from JICA.

2.2 Experimental Design

2.2.1 JICA rice training

The unit of intervention is the farmer's association. The JICA rice training project, in consultation with the Provincial Directorate of Agriculture and Fisheries (Direcção Provincial de Agricultura e Pescas, DPAP), selected 17 associations in six local units (*Localidade*) in the rainfed area and 5 associations in five local units in the irrigated area. In this impact assessment study, we focused only on the 17 rainfed associations, given the purpose of the study and the delay in the rehabilitation projects with irrigation facilities in the selected area.

The project established demonstration plots in each association, using the association's common plots, usually located at an accessible and observable location in the association's rice area.[2] In collaboration with the staff of the National Directorate of Assistance to Family Farming (Direcção Nacional de Assistência a Agricultura Familiar, DNAAF), the project provided four training sessions in the demonstration plots, teaching (1) the use of varieties selected by farmers and the project, (2) the seed selection method, (3) the nursery bed setup for seedlings, (4) land leveling, (5) bund construction, (6) straight-row transplanting or straight-row direct sowing, (7) weeding at proper timing, and (8) harvesting at the bottom of the plant, rather than the panicles. The recommended seed selection method was to remove empty seeds floating in the water. All the recommended rice varieties are *local* varieties, rather than the modern varieties developed recently, and are usually sold at markets in towns because the modern varieties are not easily accessible to the cash and market-access constrained farmers in remote areas. For the same reason, the use of inorganic fertilizers was not included in the training in the rainfed areas.

To disseminate information about the practices taught in the demonstration plots, the project selected demo farmers and invited them to the plots for training. Later, due to strong requests from some of the other member farmers, the project invited other members who wanted to participate in the training. These invited farmers were expected to teach new practices to non-participant members to accelerate the dissemination of these practices through a social learning mechanism.

2.2.2 Experimental Design and Sample

We randomized the order of demonstration farm establishments within each local unit (cluster RCT) to provide training to all associations in the project period (four years). The group of six associations that received training in the first project year is labeled Demo 1, the other six associations in the second year Demo 2, leaving five associations as the control group. We conducted a pre-training baseline survey in 2017 on the 2016–17 rice season, and after completing

[2] If the associations did not have common plots, the project leased private plots suitable for demonstration.

the training in the Demo 1 and Demo 2 groups, a follow-up survey in 2019 on the 2018–19 rice season. Since the associations are far apart and little spillover effect exists across them, we believe that the stable unit treatment value assumption (SUTVA) is not violated. The weather in the baseline rice season was normal, but the follow-up season had irregular rainfall. Hence, on average, rice yield decreased at the time of the follow-up survey.

We collected a random sample of 13 to 25 farmers proportionate to the association size from each association, generating 321 observations in the baseline survey. In the follow-up survey, we were able to collect data from 257 farmers in the baseline survey, with the attrition of 54 farmers. Our statistical analysis relies on a balanced panel of these 257 farmers in two periods (514 observations) while statistically controlling for attrition bias.

3. Descriptive Statistics

3.1 Balance test and outcomes

Table 1, Columns (1)–(5) show the baseline balance of sample households by treatment. Of the 257 farmers, 78 farmers received the treatment of demonstration plot in the first year (Demo 1) and 101 farmers did so in the second year (Demo 2), while 78 farmers in the control group did not receive training. The household characteristics consist of household size (heads), household head's schooling years (years), the log of household total asset value (000 MT), total plot area (ha) including non-survey plots, the proportion of known farmers (%), weather shock in the rice season of the survey year (dummy), and weather shock in the non-rice season immediately before the rice season of the survey year (dummy). The variable "proportion of known members" measures what percentage of sample farmers in the association is known by a sample farmer, indicating network size within the association.

The table shows that all the household characteristics, either in Demo 1 or Demo 2, except the proportion of known members, are not statistically different from those of the control group.

A joint significance test between Demo 2 and the control (shown at the bottom of the table) was statistically significant, but it became insignificant if we removed the variable of the proportion of known members (the result is not shown in the table).

Columns (6)–(8) of Table 1 compare the household characteristics by attrition status, in which we additionally compare the dummy of treatment. The table shows that although attrition had little to do with treatment, it occurred non-randomly because non-attrition households operated larger areas of farmland, knew fewer farmers in the same association, and were less likely to have experienced weather shocks in both the rice and non-rice seasons. These differences might constitute a source of bias in the impact assessment, and thus need to be managed with an appropriate econometric technique.

Table 2 shows changes in outcome variables by treatment status at the baseline season (columns (1)–(5)) and the follow-up season (columns (6)–(10)). We also present unconditional difference-in-differences (DID) estimates of the treatment effect in Table 3, which compares the *changes* in outcome variables from the baseline to the follow-up. The outcome variables we examine are the adoption of the practices demonstrated by the training, namely, the adoption of seed selection by water (= 1), setup of the nursery bed (= 1), bund construction (= 1), leveling (= 1), straight-row transplanting (= 1), conducting weeding at least once (= 1), harvesting at the bottom of the plant (= 1), use of sickle for harvesting (= 1), and use of a recommended rice variety of either Chupa (= 1), Mocuba (= 1), or Mamina (= 1). These varieties are local varieties having the characteristics of late maturity and high yield, unlike the other popular local variety Nene, which has the features of early maturity and low yield. The adoption of these three varieties is used as our outcome variable because these are the varieties preferred by farmers and recommended by the project. We also compare rice yield (t/ha) as the outcome of the project. Note that the weeding variable is empty in the baseline because we failed to collect this information correctly.

The table shows that, at the time of the baseline survey, the adoption of practices was quite low, and the differences by treatment status were statistically insignificant, except for two variables related to harvesting (harvesting at the bottom of the plant and the use of sickle) in Demo 2 group. Nevertheless, the adoption of these two practices was lower in Demo 2 group than in the control group at the pre-training time; thus, a possible higher adoption rate at post-treatment does not mean that it was higher from the beginning. Meanwhile, we observe significant differences in variety choices, which may reflect variations in local preferences.

The rice yields were low at 1,940 kg/ha in Demo 1, 1,527 kg/ha in Demo 2, and 1,975 kg/ha in the control group, which was understandable under rainfed conditions even for a normal weather season. The low yield of Demo 2 was statistically different from that of the control group at the 10% significance level. This could be the reason for the low adoption of improved harvesting methods by Demo 2. Farmers usually start using such practices when their productivity improves, that is, a causality manifests from yield to harvesting methods.[3] Even though the yield difference between Demo 2 and the control was statistically significant, we can still claim that the yield in the Demo 2 group was not higher from the beginning.

In the follow-up survey, the adoption rate of recommended practices sharply increased among the treated groups, resulting in statistically significant differences compared to the control group in most cases. When comparing yield, we must note that the follow-up season suffered from irregular rainfall, and thus the *overall* average at the study site slightly decreased from approximately 1,800 kg/ha at the baseline to about 1,700 kg/ha at follow-up. However, we can still observe differential outcomes by treatment status; the reduction for Demo 1 was marginal, and Demo 1 achieved 1,783 kg/ha. Furthermore, Demo 2 improved its yield to 1,752 kg/ha, while the yield of the control group decreased to 1,536 kg/ha. Hence, the yields of Demo 1 and Demo 2 were approximately 200 kg/ha higher than those of the control group, although the differences were not statistically significant at any conventional level. Meanwhile, if we compare the changes

[3] These harvesting practices were recommended for the ease of threshing and recycling of rice straws.

by the unconditional DID analyses in Table 3, we observe a significantly positive impact of 663 kg/ha of change in the yield of the Demo 2 group. The results of the other unconditional DID estimators are consistent with the results of the mean comparison.

3.2 Practice Adoption and its Impact

One of the key research issues of this study is to identify the importance of management practices and their adoption as a package. To shed light on this issue, we focus on five essential practices: seed test by water (S), nursery bed setup (N), bund construction (B), field leveling (L), and straight-row transplanting (TP). The practices (S) and (N) may be combined as the set of seedling preparation practices for quality seedlings. Similarly, (B) and (L) are the set of land preparation practices for even water distribution, and (TP) is a crop care practice that facilitates such crop management practices as fertilizer application, weeding, and harvesting. We cannot include weeding in the set of crop care practices due to the lack of baseline data.[4] In addition, we do not include the two recommended harvesting practices because they are not yield improving practices.

Table 4 Panel A shows the percentage of adopters of individual practices or their package and corresponding yields among the entire sample ($n = 257$) at the baseline and follow-up seasons. The asterisks on the yield values indicate the significant mean difference from the yield under no adoption based on the *t*-test. We assume that the yield increased when the farmers adopted all five practices as a package. Hence, when we calculate the yield under the solo or partial adoption from the five practices, we do not include the farmers who adopted all five practices. For example, the case of adoption (S) in the table does not include the farmers who adopted all five adopters, only the farmers who adopted (S) alone or (S) and some but not all the other practices. If the adoption of (S) alone still has an impact, yield under (S) is expected to be higher than in the case of no

[4] It is possible to show the status of weeding adoption and its impact at the follow-up. The trend of this practice is similar to those of the other practices: The yield of weeding adopters is lower than the non-adopters in the follow-up. This is partly due to self-selection; farmers who suffered weed problems did weeding more frequently.

adoption. The table also shows the case combining any single or partial adoptions of five practices at one row above the case of full adoption. Hence, the sum of "No adoption," "Any single or partial adoption," and "All 5 practices" is 100%.

Table 4 shows these two features. First, unexpectedly, at baseline, the case of no adoption showed the highest yield. This may be due to self-selection by farmers who could achieve high productivity with conventional practices under favorable agroecological conditions. Second, at the follow-up, the adoption of all five practices gave the highest yield, followed by the adoption of (B)+(L)+(TP), although this was not statistically significant. For the same reason as with non-adopters, the adoption of a practice could also have a self-selection problem. Farmers that can utilize the new practices fully and thus achieve a higher yield selectively adopt new practices. To control for the self-selection issue in adoption analyses as well as other controls, more statistically rigorous analyses will be provided in the next section.

Panel B in Table 4 shows the impact of variety adoption. Except for the use of the Mocuba variety at baseline, we did not find significant differences in yield. This may be because each farmer already used a variety suitable for their local conditions.

Another critical research issue is the effectiveness of extension methods. Table 5 lists the most important information sources for new practices among adopters in the follow-up season. The sources are classified into six categories: through demonstration plot participation, from extension workers, from other farmers, through the observation of the plots of unrecognized farmers, and the case where the practice was ever known. The results indicate that the demonstration plots or the extension workers were the two key sources where the farmers noticed the new practices for the first time, indicating that these two conventional means could at least serve as a starting point of dissemination to make farmers aware of the new practices.

To consider not only the influence of the demonstration plot training but also that of social learning, Table 6 compares farmers' characteristics between the full adopters of all five practices and the partial or non-adopters in the treated groups (n = 179). We limited our sample to the treated groups because demonstration plot effects and their dissemination through social learning can only appear in these groups.[5]

Five features were identified. First, the yield was significantly higher (by 534 kg/ha) for the full adopters. Second, the farmers who participated in all four training sessions were more likely to be full adopters (51.6% vs. 23.6%). Third, the proportions of known members are not statistically different, implying that the network size *per se* does not matter. Fourth, knowing the would-be adopters at the baseline seems to matter. Therefore, careful explanation may be needed. The variable "No. of baseline known members who adopted all five practices" measures among the members whom a sample farmer had known since the baseline, how many of them fully adopted the practices. We set the known member network at baseline to avoid endogenous network formation during and after training. A larger number in this variable (3.9 against 0.7) implies that at the time of baseline, knowing more farmers who would adopt all five practices after training meant an increased likelihood of being a full adopter oneself. There are two possible mechanisms for this phenomenon. First, this can happen when known members share similar background characteristics, for example, the ability to learn and risk preferences. Second, this can occur when information sharing exists among known farmers. The former is labeled a correlated social effect and the latter social learning or spillover. Unless we exclude the former effects, we cannot identify the importance of social learning. However, identifying social learning, known as the reflection problem, is statistically difficult, as explained later (Manski 1993). The fifth feature is that, as shown at the bottom of the table, the other household characteristics were not significantly different, except for the lower asset value among the full adopters.

Table 7 examines the complementarity between demo participation and social network effects by comparing four combinations of the two statuses of demo participation (participated in all four training sessions or not) by the two statuses of social network (knew at least one full

[5] We confirmed from our data that the separation of partial adopters and non-adopters into two groups does not change our argument. Hence, for simpler expression, we combine them in one category.

adopter or not at all). The table indicates that in the case of Yes-Yes, the adoption rate reached 50.9%, compared to 3.4% in the case of No-No. This increase in the adoption rate exceeds the sum of the solo effect of each case (Yes-No and No-Yes, 8.3 + 30.0 = 38.3), implying the existence of complementary effects between the two extension methods.

In summary, Tables 1 to 3 indicate that our RCT guaranteed a balanced sample for impact evaluation of a possible positive impact of farm management practice training. Table 4 suggests that a positive impact is more likely to be achieved when the recommended practices are adopted as a package of all five practices, rather than the partial or individual adoption of any of them. Tables 5 to 7 imply that both conventional (FFS) and contemporary (F2FE) approaches may be important not only because each contributes to the adoption of the full package but also because the two approaches may have complementary effects.

We examine these effects using regression analyses in the next section. Unfortunately, however, we have to leave the last issue, the examination of the effectiveness of each extension approach and its complementarity, for future treatment because of the endogeneity issue that cannot be solved in our RCT setting. The participation of training in demonstration plots is endogenously chosen by farmers in the trained associations. At the same time, networking and social learning are also endogenous because farmers may become acquainted during their training at the demonstration plots and influence each other when they make adoption decisions. In addition, unless we can assure the exogeneity of network formation, we cannot solve the reflection problem. In this regard, the analyses with the sample of *trained association* (consisting of Demo 1 and Demo 2 only and no control group included) must handle two types of endogenous variables, but our RCT provides only one exogenous variation, whether they received training in the first round (Demo 1) or second round (Demo 2). Hence, we do not go beyond the descriptive analyses regarding the extension method issue. The rest of the paper focuses only on regression analyses of the impact of training as well as the impact of the full adoption of the five key practices.

4. Impact Assessment

4.1 Impact of training

To assess the causal influence of the provision of training on the outcomes of our interest, we estimate intention-to-treat (ITT) effects by employing an analysis of covariance (ANCOVA) model specified as below (McKenzie 2012).

$$Y_{ijk1} = \beta_0 + \gamma Y_{ijk0} + \beta_1 D_{jk}^1 + \beta_2 D_{jk}^2 + \boldsymbol{X}_{ijk0}\boldsymbol{\delta} + \eta_k + \varepsilon_{ijk1} \quad (1)$$

where Y_{ijk1} and Y_{ijk0} are the follow-up and baseline outcome variables of the most important rice plot of household *i* in association *j* in local unit (*Localidade*) *k*; D_{jk}^1 and D_{jk}^2 are the treatment dummy variables, equal to 1 if association *j* in local unit *k* sets up the demonstration plot in the first round (Demo 1) or the second round (Demo 2), respectively; $\boldsymbol{X}_{ijk0}$ is a set of baseline control variables; η_k is the local unit fixed effect; ε_{ijk1} is the unobserved error term. Our primary outcome variable Y_{ijkt} is the rice yield (kg/ha). Our Y_{ijkt} also includes individual practices, the package of five practices, and variety adoption. When the outcome is binary, the model becomes a linear probability model. Our baseline control variables ($\boldsymbol{X}_{ijk0}$) are the variables used in the balance test in Table 1, and the squared terms for household size and total plot area.

A possible attrition bias was adjusted using the inverse-probability weighting method suggested by Wooldridge (2010). We run a probit regression model that estimates the probability of non-attrition and use the inverse of the probability as weights in equation (1).[6] The probit regression results are presented in Appendix Table A1.

Table 8 shows the estimation results of the treatment effects (β_1 and β_2) in Equation (1). Hereafter, all the results present wild bootstrap cluster robust *p*-values because the number of clusters in our data is less than 42, the threshold suggested by Angrist and Pischke (2009).[7] The

[6] The explanatory variables consist of the same variables in ***X***s and the squared term of the head's education.
[7] For wild bootstrap, see Wooldridge (2010) and Roodman et al. (2019)

t-test of an equal impact between Demo 1 and Demo 2 (i.e., $\beta_1 = \beta_2$,) is shown in the lower part of the table. The full regression results with the other control variables are listed in Table A2 in the Appendix.

The results on the yield in Table 8 column (1) indicate that the project increased the yield of the Demo 1 group by 545.5 kg/ha at a p-value of 7.95% and that of the Demo 2 group by 447.5 kg/ha at a p-value of 6.50%, which corresponds to a 35.5% or 29.1% increase from the control group yield, respectively (see the control group mean of 1,535 kg/ha at the lower part of the table).[8] The t-test of equal impact does not reject the null hypothesis, indicating that a one-year lag in training implementation did not create a significant disadvantage. However, the magnitude is higher in Demo 1 by 98 kg/ha.

As the high adoption rates of the practices at Demos 1 and 2 in Table 2 suggest, the impact of the training for those outcomes is positive and statistically highly significant (columns (2)–(6)), with no statistical difference between β_1 and β_2. The impact of training for the full adoption of five practices (Column (7)) shows a significant result in the Demo 1 group at a p-value of 6.3%, while Demo 2 gives a positive coefficient at 20% of the p-value, implying that a sequential adoption of five practices requires time. The results for variety adoption (columns (8)–(10)) are ambiguous.

4.2 Impact of practice adoption on rice yield

Taking advantage of a panel data structure, we employ a fixed-effect model to investigate the impact of practice adoption on yield. Our base model is specified as:

$$Y_{ijkt} = \beta_0 + \beta_1 M_{ijkt}^{f} + \boldsymbol{X}_{ijkt}\boldsymbol{\delta} + \lambda_0 T_t + \sum_{k=1}^{5} \lambda_k (T_t \times L_k) + \mu_{ijk} + \varepsilon_{ijkt} \quad (2)$$

[8] As a robustness check, we combine Demo 1 and Demo 2 dummies and estimate the impact of the training as a whole. The estimate is 481.9 kg/ha at a p-value of 3.7%.

where Y_{ijkt} is the rice yield of plot-household *i* in association *j* in local unit *k* at time *t*; M^f is a dummy for the full adoption of all five practices; ***X*** is a set of controls; *T* is a time trend (= 1 at the follow-up); L_k is a local unit dummy where $(T_t \times L_k)$ captures the local unit-specific time trend, μ_{ijk} is the plot-household fixed effect, and ε_{ijkt} is the unobserved error term. In the panel analysis, ***X*** does not include the head's education and log of asset value because these variables change little in the short run (and thus can be regarded as a de-facto household fixed effect) and hence were not included in the follow-up survey. Since ***X*** consists of household characteristics and weather shocks, we may regard the estimation model as a reduced-form yield function, retaining only M^f as the farmer's choice variable.

To determine the effect of partial or individual adoption after controlling for full adoption, we estimate the model as follows:

$$Y_{ijkt} = \beta_0 + \beta_1 M^f_{ijkt} + \beta_2 M^p_{ijkt} + \boldsymbol{X}_{ijkt}\boldsymbol{\delta} + \lambda_0 T_t + \sum_{k=1}^{5} \lambda_k (T_t \times L_k) + \mu_{ijk} + \varepsilon_{ijkt} \quad (3)$$

where M^p is a dummy for partial or individual adoption, and the definition is the same as in Table 4. We estimate Equation (3) separately for each M^p. For example, to estimate the partial adoption of (S), M^p becomes 1 when (S) is used alone or together with other practices, but not all five together. Since the base category for this case consists of either non-adopters or other partial adopters, the impact of (S) may be masked if the partial adoption of the other practices has a positive impact. Meanwhile, note that M^p for the case of *any* partial adoption becomes 1 when a farmer solely or partially adopts any practices, but not all. Hence, the base category for this case is the non-adopter alone, indicating a general impact of all kinds of partial or individual adoption.

The impact of variety adoption is estimated by the following model:

$$Y_{ijkt} = \beta_0 + \beta_1 M^f_{ijkt} + \beta_3 V^s_{ijkt} + \boldsymbol{X}_{ijkt}\boldsymbol{\delta} + \lambda_0 T_t + \sum_{k=1}^{5} \lambda_k (T_t \times L_k) + \mu_{ijk} + \varepsilon_{ijkt} \quad (4)$$

where V^s is a dummy variable for the adoption of a particular variety s. We estimate Equation (4) separately for each variety.

Two econometric issues are addressed. First, to control for a possible attrition bias, we apply the same inverse probability weighting method. Second, the endogeneity of practice and variety adoption (M^f, M^p, and V^s) might remain even after controlling for unobserved plot-household level fixed effects such as soil fertility and farm management ability. We apply an instrumental variable (IV) method by taking advantage of the RCT setting of our survey. Equations (2) to (4) have at most two endogenous variables, and Demo 1 and Demo 2 dummies are used to identify instrumental variables.

Table 9 presents the estimation results, together with the percentage of adoption replicated from Table 4. The full regression results with the other control variables are shown in Appendix Tables A3-1 to A3-3. The most important finding from the FE-IV model is that the yield significantly increased when the farmers adopted the package of five practices. The magnitude of impact (β_1 in Model (2)), 1,032 kg/ha, is reasonable because it is consistent with the magnitude of 1.2 t/ha shown in the project report as the average impact among advanced practice adopters. Meanwhile, the impacts of partial or single adoption of the practices (β_2 in Model (3)) were not statistically significant, although the FE-IV analyses yielded positive values for all the cases. One reason could be the small number of adopters (e.g., the case of B+L+TP, from 0% to 1%), but even when the increase in adopters is substantial, no significant results are obtained.[9] Presumably, the yield improvement impact is not stable unless the complementary practices are adopted as a package, and this argument particularly holds under rainfed conditions where water control is crucially important to assure the harvest. The impact of variety adoption (β_3 in Model (4)) was also insignificant.

[9] The changes in "Any partial adoption" is small from 63% to 67%, but the composition of the farmers differ between two periods, resulting in sufficient variation for our panel regression analysis.

5. Conclusion

This study evaluated the RCT of rice farm management training in the rainfed lowlands of Mozambique. Our analyses found a positive impact of the training on the adoption of recommended practices and land productivity (yield), indicating the importance of basic management practices for SSA's rice GRs. Our analyses also revealed that the practices are best adopted as a package. Our findings indicate that, since it was possible to realize a positive impact in rainfed lowlands without relying on purchased modern inputs such as improved modern seeds and inorganic fertilizer, the provision of management training could be an effective development strategy to improve the livelihood of poor farmers in remote areas. Note, however, that, as the Asian experience clearly indicates, the potential impact under rainfed conditions without modern inputs is limited, being not as high as that of irrigated conditions with modern inputs. It is an important future research agenda to assess the potential of irrigation development as a long-term development strategy in SSA.

Among the many possible training approaches, our case can be regarded as a combination of the FFS and F2FE approaches without a monetary incentive for those farmers who teach new practices to others. Our results relied on data from relatively small rice farming communities. Further research on external validity would provide a better understanding of the appropriate training design. Our descriptive analyses suggest complementarity between FFS and F2FE. Disentangling the impact of each approach and identifying the complementarity would also contribute to a better understanding than was possible in our current experimental setting.

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Table 1: Baseline balance of sample households by treatment and attrition status

Variable	(1) Demo 1 Mean/SE	(2) Demo 2 Mean/SE	(3) Control Mean/SE	(4) Difference (1)-(3)	(5) Difference (2)-(3)	(6) Non attrition Mean/SE	(7) Attrition Mean/SE	(8) Difference
Treated (=1)						0.696	0.796	-0.100
						[0.029]	[0.055]	
Household size	3.718	4.050	4.282	-0.564	-0.233	3.634	4.352	-0.718
	[0.226]	[0.211]	[0.299]			[0.220]	[0.542]	
Head's education (years)	3.846	3.574	3.500	0.346	0.074	3.634	4.352	-0.718
	[0.427]	[0.334]	[0.398]			[0.220]	[0.542]	
Log of asset value	7.563	7.677	7.477	0.085	0.199	7.581	7.208	0.374
	[0.184]	[0.139]	[0.247]			[0.108]	[0.259]	
Total plot area (ha)	0.813	0.621	0.703	0.110	-0.082	0.704	0.413	0.291**
	[0.122]	[0.078]	[0.107]			[0.058]	[0.044]	
Proportion of known members (%)	32.869	55.789	41.660	-8.79*	14.13**	44.545	72.627	-28.082***
	[2.933]	[3.713]	[4.028]			[2.179]	[4.679]	
Weather shock in the last rice season (=1)	0.115	0.149	0.154	-0.038	-0.005	0.140	0.315	-0.175***
	[0.036]	[0.036]	[0.041]			[0.022]	[0.064]	
Weather shock in the last non-rice season (=1)	0.795	0.772	0.833	-0.038	-0.061	0.798	0.907	-0.110*
	[0.046]	[0.042]	[0.042]			[0.025]	[0.040]	
N	78	101	78			257	54	
F-test of joint significance (F-stat)				1.641	2.577**			4.216***
F-test, number of observations				156	179			311

The value displayed for t-tests are the differences in the means across the groups. The value displayed for F-tests are the F-statistics. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.
Source by Authors

Table 2: Changes in outcome variables by treatment status: baseline and follow-up

	Baseline					Follow-up				
Variable	(1) Demo 1 Mean/SE	(2) Demo 2 Mean/SE	(3) Control Mean/SE	(4) Difference (1)-(3)	(5) Difference (2)-(3)	(6) Demo 1 Mean/SE	(7) Demo 2 Mean/SE	(8) Control Mean/SE	(9) Difference (6)-(8)	(10) Difference (7)-(8)
Seedlings preparation practices										
Seed test, water (=1)	0.256	0.337	0.231	0.026	0.106	0.769	0.644	0.141	0.628***	0.503***
	[0.050]	[0.047]	[0.048]			[0.048]	[0.048]	[0.040]		
Nursery bed set up (=1)	0.269	0.386	0.333	-0.064	0.053	0.872	0.812	0.333	0.538***	0.479***
	[0.051]	[0.049]	[0.054]			[0.038]	[0.039]	[0.054]		
Land preparation practices										
Plot bunding (=1)	0.192	0.267	0.218	-0.026	0.049	0.474	0.495	0.192	0.282***	0.303***
	[0.045]	[0.044]	[0.047]			[0.057]	[0.050]	[0.045]		
Plot leveling (=1)	0.141	0.188	0.244	-0.103	-0.055	0.667	0.455	0.038	0.628***	0.417***
	[0.040]	[0.039]	[0.049]			[0.054]	[0.050]	[0.022]		
Crop care practices										
Straight-row transplanting (=1)	0.013	0.000	0.000	0.013	N/A	0.462	0.356	0.000	0.462***	0.356***
	[0.013]	[0.000]	[0.000]			[0.057]	[0.048]	[0.000]		
Weeding at least once (=1)	N/A	N/A	N/A	N/A	N/A	0.628	0.455	0.359	0.269***	0.096
						[0.055]	[0.050]	[0.055]		
Harvesting practices										
Harvesting at the bottom of plant (=1)	0.038	0.010	0.051	-0.013	-0.041*	0.526	0.465	0.192	0.333***	0.273***
	[0.022]	[0.010]	[0.025]			[0.057]	[0.050]	[0.045]		
Using sickle to harvest	0.295	0.277	0.410	-0.115	-0.133*	0.615	0.426	0.321	0.295***	0.105
	[0.052]	[0.045]	[0.056]			[0.055]	[0.049]	[0.053]		
Rice varieties										
Using Chupa variety (=1)	0.128	0.050	0.026	0.103**	0.024	0.231	0.337	0.064	0.167***	0.273***
	[0.038]	[0.022]	[0.018]			[0.048]	[0.047]	[0.028]		
Using Mocuba variety (=1)	0.179	0.168	0.295	-0.115*	-0.127**	0.359	0.168	0.231	0.128*	-0.062
	[0.044]	[0.037]	[0.052]			[0.055]	[0.037]	[0.048]		
Using Mamima variety (=1)	0.179	0.139	0.269	-0.090	-0.131**	0.179	0.119	0.167	0.013	-0.048
	[0.044]	[0.035]	[0.051]			[0.044]	[0.032]	[0.042]		
Output										
Rice yield (ha)	1939.7	1527.1	1974.9	-35.191	-447.794*	1782.5	1751.5	1535.8	246.659	215.661
	[172.671]	[139.327]	[197.380]			[126.150]	[109.771]	[131.771]		
N	78	101	78			78	101	78		
F-test of joint significance (F-stat)				2.096**	2.294***				18.186***	11.436***
F-test, number of observations				156	179				156	179

N/A: No data available or no statistical comparison possible. The value displayed for *t*-tests are the differences in the means across the groups; The value displayed for *F*-tests are the F-statistics; ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.
Source by Authors

Table 3: Changes in outcome variables by treatment status – unconditional DID: baseline and follow-up

	Unconditional DID Follow-up - baseline	
	Demo 1	Demo 2
Variable		
Seed test, water (=1)	0.603***	0.397**
	[0.000]	[0.000]
Setting up a nursery bed in the plot (=1)	0.603***	0.426**
	[0.000]	[0.000]
Plot bunding (=1)	0.308***	0.253***
	[0.00255]	[0.00824]
Plot leveling (=1)	0.731***	0.472***
	[0.00]	[0.00]
Straight-row transplanting (=1)	0.449***	0.356***
	[0.000]	[0.000]
Harvesting at the bottom of plant (=1)	0.346***	0.314***
	[0.000]	[0.000]
Using sickle to harvest	0.410***	0.238**
	[0.00]	[0.019]
Using Chupa variety (=1)	0.064	0.249***
	[0.396]	[0.000]
Using Mocupa variety (=1)	0.244***	0.064
	[0.009]	[0.470]
Using Mamima variety (=1)	0.103	0.083
	[0.229]	[0.302]
Rice yield (kg/ha)	281.85	663.45**
	[0.358]	[0.0219]
N	514	514

p-values in brackets; *** and ** indicate significance at the 1 and 5 percent critical level.
Source by Authors

Table 4: Practice and variety adoption and yield in the follow-up survey (balanced rainfed sample)

Panel A: Key practices

	---------- Baseline ----------		---------- Follow-up ----------	
Adoption status	Percentage of farmers (%)	Yield (kg/ha)	Percentage of farmers (%)	Yield (kg/ha)
No adoption	37	2098	20	1805
Partial adoption[a]				
(S) Seed test by water	28	1295***	41	1536
(N) Nursery bed set up	33	1611*	56	1596
(S)+(N)	11	657***	35	1552
(B) Bund construction	23	1262***	28	1614
(L) Leveling	19	1740	27	1507
(B)+(L)	8	1924	11	1596
(TP) Straight-row planting	0.4	2442	16	1326**
(S)+(N)+(B)+(L)	2	1276	5	1384
(S)+(N)+(TP)	0	na	14	1227
(B)+(L)+(TP)	0	na	1	2158
Any single or partial adoption	63	1609**	67	1571
Full adoption				
All 5 practices (S)+(N)+(B)+(L)+(TP)	0	na	12	2206

a) Individual or particle adoption does not include the case of all 5 adoption; *** p<0.01, ** p<0.05, the mean difference from the case of "No adoption"(0); Sample size = 257.

Panel B: Key varieties

	---------- Baseline ----------		---------- Follow-up ----------	
Adoption status	Percentage of farmers (%)	Yield (kg/ha)	Percentage of farmers (%)	Yield (kg/ha)
Neither Chupa, Mamima, nor Mocuba	53	1678	38	1698
Variety Chupa	7	1792	22	1493
Variety Manima	19	1486	15	1572
Variety Mocuba	21	2316**	25	1949

** p<0.05, the mean difference from the case of "Neither Chupa, Mamima, nor Mocuba"; Sample size = 257.

Source by Authors

Table 5: Practice adoption and the most important information source in the follow-up survey

Practices	Source of information among adopters (%)				
	Demonstration plot participation	Extension workers	From other farmers	Observation	Ever Known
(S) Seed test by water	39.39	55.56	4.05	0	0
(N) Nursery bed set up	39.40	55.60	5.05	0	0
(B) Bund construction	44.12	25.49	7.84	4.90	17.65
(L) Leveling	37.62	56.44	0	3.96	1.98
(TP) Straight-row transplanting	33.33	63.89	2.78	0	0
Rice variety (Mamima)	12.82	12.82	0	10.26	64.1
Rice variety (Mocuba)	9.52	68.25	7.94	7.94	6.35
Rice variety (Chupa)	29.82	38.60	3.51	15.79	12.28

Sample size = 257.

Source by Authors

Table 6: Farmer characteristics by the adoption of five key practices

	(1) Full adopters of 5 key practices	(2) Partial or non adopters	*t*-test Difference
Variable	Mean/SE	Mean/SE	(1)-(2)
Rice yield (kg/ha) at the follow-up	2206.895	1672.425	534.470**
	[237.100]	[85.144]	
Join all 4 demonstration plot training sessions (%)	0.516	0.236	0.280***
	[0.091]	[0.035]	
Join at least one demonstration plot training but not all (%)	0.484	0.608	-0.124
	[0.091]	[0.040]	
Join none of the demonstration plot training sessions (%)	0.000	0.074	-0.074
	[0.000]	[0.022]	
Proportion of baseline known members (%)	40.956	46.816	-5.860
	[5.504]	[2.916]	
No. of baseline known members who adopted all 5 practices	3.903	0.716	3.187***
	[0.789]	[0.172]	
Household size	4.258	3.831	0.427
	[0.365]	[0.171]	
Head's education (years)	3.387	3.757	-0.370
	[0.734]	[0.281]	
Log of asset	7.216	7.713	-0.497*
	[0.248]	[0.125]	
Total plot area (ha)	0.756	0.694	0.062
	[0.255]	[0.065]	
N	31	148	
F-test of joint significance (F-stat)			7.063***
F-test, number of observations			179

The value displayed for t-tests are the differences in the means across the groups.
The value displayed for F-tests are the F-statistics.
***, **, and * indicate significance at the 1, 5, and 10 percent critical level.
Source by Authors

Table 7: Source of information and full practice adoption in the treated associations

Sources of information			
Participated all 4 demonstration plot training sessions	Knew at least one full adopter in the baseline known members	No. of farmers	Full adopter in the corresponding case (%)
No	No	88	3.4
Yes	No	24	8.3
No	Yes	40	30.0
Yes	Yes	27	50.9

Sample size = 179.
Source by Authors

Table 8: Estimated results of ANCOVA model on the impact of training: rice productivity and technology adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Rice yield	Seed test by water	Nursery bed set up	Bund	Leveling	Straight-row TP	Use all 5	Use Mamima	Use Mocuba	Use Chupa
Demo 1 (treatment)	545.5*	0.570***	0.592***	0.376**	0.609**	0.508*	0.367*	0.0903*	0.0895	0.0899
	[0.0795]	[0.0085]	[0.0005]	[0.0440]	[0.0390]	[0.0750]	[0.0635]	[0.0985]	[0.3710]	[0.6010]
Demo 2 (treatment)	447.5*	0.479*	0.461***	0.326**	0.416**	0.449**	0.200	-0.00583	-0.0568	0.289
	[0.0650]	[0.0710]	[0.0000]	[0.0265]	[0.0400]	[0.0100]	[0.2015]	[0.8485]	[0.7730]	[0.1380]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local unit FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
t-test (Demo 1=Demo 2)	0.8372	0.7911	1.3768	0.5446	1.3559	0.4146	1.7405	2.0472*	1.8529	-1.7335
	[0.5005]	[0.5795]	[0.3330]	[0.7695]	[0.4005]	[0.7605]	[0.1900]	[0.0570]	[0.1910]	[0.2235]
Control mean value	1535	0.141	0.333	0.192	0.038	0.00	NA	0.167	0.231	0.064
Observations	257	257	257	257	257	257	257	257	257	257
R-squared	0.363	0.300	0.413	0.510	0.395	0.380	0.418	0.403	0.525	0.302

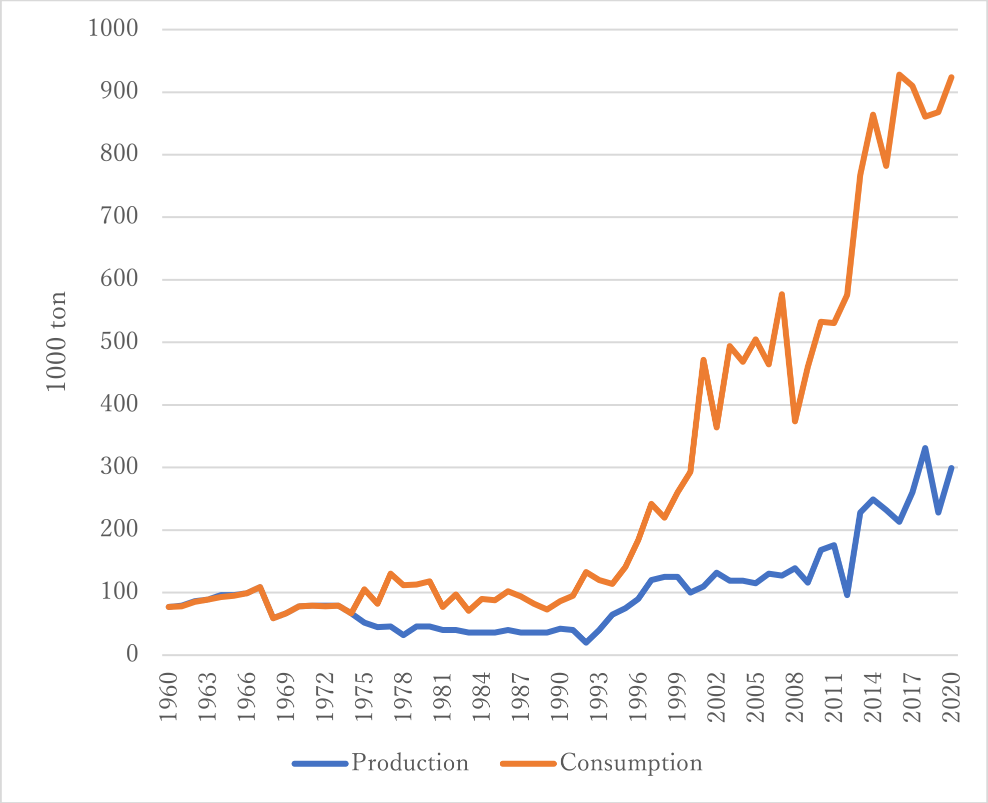
Wild bootstrap cluster robust *p*-values in brackets; Inverse probability weights are used to control for attrition bias (See Table A1 for the probit analysis of non-attrition).
*** p<0.01, ** p<0.05, * p<0.1.
See Appendix Table A2 for full regression results.
Source by Authors

Table 9: Impact of practice adoption on rice yield

	% of adopters		Impact of adoption*	
	Baseline	Follow-up	FE-OLS	FE-IV
β_1 in Model (2)				
All 5 practices	0	12	749.3***	1,032*
			[0.0060]	[0.0831]
β_2 in Model (3)				
Any single or partial adoption	63	67	-125.1	424.5
			[0.5000]	[0.4920]
S+N+B+L	2	5	321.4	642.0
			[0.4434]	[0.6517]
S+N+TP	0	14	-162.1	1,178
			[0.3063]	[0.3854]
B+L+TP	0	1	538.8	3,826
			[0.8789]	[0.2823]
S	28	41	-40.42	600.7
			[0.8258]	[0.1972]
N	33	56	-130.5	441.5
			[0.6446]	[0.5275]
S+N	11	35	27.20	682.9
			[0.8919]	[0.1992]
B	23	28	237.2*	773
			[0.0711]	[0.2102]
L	19	27	-14.39	914
			[0.9590]	[0.1321]
B+L	8	11	438.5	1,081
			[0.1872]	[0.4515]
TP	0.4	16	-137.8	1,123
			[0.5425]	[0.2803]
β_3 in Model (4)				
Variety Chupa	7	22	-89.92	849.1
			[0.6466]	[0.2623]
Variety Mamima	9	15	206.5	271.7
			[0.1351]	[0.8108]
Variety Mocuba	21	25	73.72	-102.3
			[0.7077]	[0.9139]

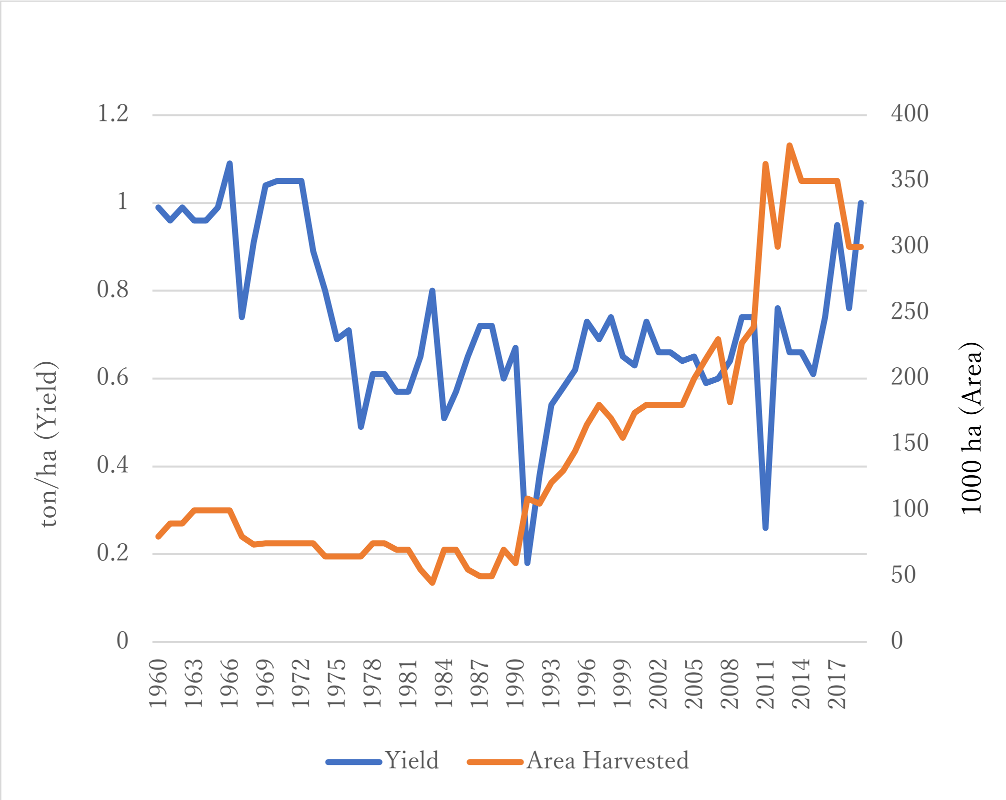
S: Seed test by water, N: Nursery bed set up, B Bund, L: Leveling; TP: Straight-row transplanting.
* For the adoption impact of partial adoption, the impact of full adoption of 5 key practices is controlled for.
Wild bootstrap cluster robust p-values in brackets; Inverse probability weights are used to control for attrition bias (See Table A1 for the probit analysis of non-attrition).
*** p<0.01, ** p<0.05, * p<0.1.
See Appendix Table A3 for full regression results.
Source by Authors

Figure 1: Production and consumption of rice (milled bases) in Mozambique, 1960 - 2020



Data Sources: USDA: PS&D Online April 2021; USBC: International Data Base, August 2006.

Figure 2: Area harvested and yield of rice (milled bases) in Mozambique, 1960 -2020



Data Sources: USDA: PS&D Online April 2021; USBC: International Data Base, August 2006.

Figure 3: Study site

Source: Google maps, accessed May 18th, 2021.

Appendix

Table A1: Estimation results for the non-attrition probit model

	Non-attrition = 1
Household size	-0.00415
	[0.9165]
Head's education (years)	-0.0335*
	[0.0800]
Head's education squared	0.000253*
	[0.0705]
Log of asset	0.0866*
	[0.0600]
Total plot area (ha)	-0.594
	[0.6500]
Total plot area squared	0.521
	[0.4050]
Proportion of known members (%)	-0.0107*
	[0.0630]
Weather shock in the last rice season (=1)	-0.341
	[0.1200]
Weather shock in the last non-rice season (=1)	-0.248
	[0.3970]
Constant	1.382**
	[0.0235]
Observations	311

Wild bootstrap cluster robust *p*-values in brackets.
** p<0.05, * p<0.1.
Source by Authors

Table A2: Full estimation results of ANCOVA model on the impact of training: rice productivity and technology adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Rice yield	Seed test by water	Nursery bed set up	Bund	Leveling	Straight-row TP	Use all 5	Use Mamima	Use Mocuba	Use Chupa
Y0	0.139**	-0.0585	0.214**	0.0530	0.0596	-0.207	N/A	-0.0325	0.141	0.0469
	[0.0250]	[0.1760]	[0.0230]	[0.6040]	[0.2805]	[0.8035]		[0.6185]	[0.1710]	[0.4885]
Demo 1 (treatment)	545.5*	0.570***	0.592***	0.376**	0.609**	0.508*	0.367*	0.0903*	0.0895	0.0899
	[0.0795]	[0.0085]	[0.0005]	[0.0440]	[0.0390]	[0.0750]	[0.0635]	[0.0985]	[0.3710]	[0.6010]
Demo 2 (treatment)	447.5*	0.479*	0.461***	0.326**	0.416**	0.449**	0.200	-0.00583	-0.0568	0.289
	[0.0650]	[0.0710]	[0.0000]	[0.0265]	[0.0400]	[0.0100]	[0.2015]	[0.8485]	[0.7730]	[0.1380]
Household size	-50.13	0.00336	0.0117	-0.0886**	-0.0470	-0.0124	-0.0101	-0.0516	0.0243	0.0241
	[0.7935]	[0.9415]	[0.7195]	[0.0440]	[0.4720]	[0.6835]	[0.6135]	[0.1060]	[0.6995]	[0.5025]
Household size squared	6.379	-1.21e-05	-0.00158	0.00943**	0.00386	0.000529	0.00189	0.00537	-0.00286	-0.00510
	[0.7400]	[0.9980]	[0.6385]	[0.0310]	[0.5495]	[0.8305]	[0.3550]	[0.1430]	[0.5665]	[0.1475]
Head's education (years)	-9.454	-0.00581	-0.0110	-0.00308	6.11e-05	-0.0131	0.00323	-0.00110	-0.00589	0.00546
	[0.5520]	[0.4375]	[0.2720]	[0.6505]	[0.9975]	[0.2320]	[0.6085]	[0.7480]	[0.1570]	[0.5470]
Log of asset	52.09	0.0221	0.000723	0.0210	0.000923	0.0118**	0.00708	-0.00833	0.0223	-0.0249*
	[0.1280]	[0.1715]	[0.9640]	[0.1750]	[0.9670]	[0.0115]	[0.1505]	[0.1940]	[0.1080]	[0.0655]
Total plot area (ha)	-1,563***	-0.0910	-0.0191	0.0476	-0.201*	-0.0425	-0.141	0.156*	0.0575	0.0456
	[0.0005]	[0.4460]	[0.8800]	[0.5050]	[0.0755]	[0.6575]	[0.1020]	[0.0620]	[0.4120]	[0.3550]
Total plot area squared	240.6***	0.0367	0.0141	-0.00230	0.0574**	0.0246	0.0353*	-0.0295	-0.0123	-0.00121
	[0.0000]	[0.1000]	[0.6005]	[0.8695]	[0.0270]	[0.1820]	[0.0675]	[0.1410]	[0.3420]	[0.9190]
Proportion of known members (%)	3.53	-0.00178	-0.000388	0.00213	0.000296	0.000119	0.000352	-0.000444	0.000147	-0.00120
	[0.1385]	[0.4065]	[0.8235]	[0.1070]	[0.9145]	[0.9570]	[0.9355]	[0.7640]	[0.9340]	[0.3040]
Weather shock rice	130.8	0.0317	-0.0932	0.0340	-0.152	0.0719	0.0852	-0.0312	-0.0490	-0.104
	[0.6210]	[0.6850]	[0.2270]	[0.2275]	[0.3960]	[0.3735]	[0.3490]	[0.6725]	[0.2080]	[0.3905]
Weather shock non-rice	-140.4	-0.136	-0.0140	0.0651	0.125	-0.0616	-0.0155	0.0665*	-0.0308	0.0596
	[0.7535]	[0.1005]	[0.8585]	[0.1620]	[0.1460]	[0.3565]	[0.5815]	[0.0860]	[0.5400]	[0.3820]
Constant	1,735***	0.222	0.266*	0.173	0.0178	0.0317	0.0190	0.0961	0.226	0.316***
	[0.0010]	[0.1255]	[0.0960]	[0.4895]	[0.9205]	[0.8035]	[0.8065]	[0.4015]	[0.4950]	[0.0080]
Local unit FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
t-test (Demo 1=Demo 2)	0.8372	0.7911	1.3768	0.5446	1.3559	0.4146	1.7405	2.0472*	1.8529	-1.7335
	[0.5005]	[0.5795]	[0.3330]	[0.7695]	[0.4005]	[0.7605]	[0.1900]	[0.0570]	[0.1910]	[0.2235]
Control mean value	1535	0.141	0.333	0.192	0.038	0.00	NA	0.167	0.231	0.064
Observations	257	257	257	257	257	257	257	257	257	257
R-squared	0.363	0.300	0.413	0.510	0.395	0.380	0.418	0.403	0.525	0.302

Wild bootstrap cluster robust p-values in brackets; Inverse probability weights are used to control for attrition bias (See Table A1 for the probit analysis of non-attrition).
N/A: No variation in the baseline observations. *** p<0.01, ** p<0.05, * p<0.1.
Source by Authors

Table A3-1: Full estimation results of the impact of practice adoption

VARIABLES	(1) Rice yield na FE-OLS	(2) Rice yield na FE-IV	(3) Rice yield Any partial FE-OLS	(4) Rice yield Any partial FE-IV	(5) Rice yield S+N+B+L FE-OLS	(6) Rice yield S+N+B+L FE-IV	(7) Rice yield S+N+TP FE-OLS	(8) Rice yield S+N+TP FE-IV	(9) Rice yield B+L+TP FE-OLS	(10) Rice yield B+L+TP FE-IV
Full adoption of all 5 key practices	749.3***	1,032*	668.6**	983.5	760.1***	1,060***	747.9***	858.4	759.8***	743
	[0.0060]	[0.0831]	[0.0150]	[0.1860]	[0.0070]	[0.0681]	[0.0020]	[0.2052]	[0.0070]	[0.2553]
Partial adoption of 5 key practices			-125.1	424.5	321.4	642.0	-162.1	1,178	538.8	3,826
			[0.500]	[0.4920]	[0.4434]	[0.6517]	[0.3063]	[0.3854]	[0.8789]	[0.2823]
Household size	169.7	171.1	167.3	177.3	172.6	177.1*	166.5	193.3	162.9	121.6
	[0.1151]	[0.1081]	[0.1230]	[0.1150]	[0.1001]	[0.0941]	[0.1101]	[0.1131]	[0.1371]	[0.4474]
Household size squared	-12.25	-12.28	-11.93	-13.31	-12.16	-12.1	-11.72	-16.08	-11.80	-9.088
	[0.1351]	[0.1471]	[0.1570]	[0.1390]	[0.1532]	[0.1371]	[0.1371]	[0.1792]	[0.1552]	[0.4184]
Proportion of known farmers	-6.718	-6.851	-6.831	-6.316	-7.058	-7.533*	-6.794	-6.214	-6.492	-5.076
	[0.1882]	[0.1662]	[0.1690]	[0.1400]	[0.1632]	[0.0801]	[0.1642]	[0.1992]	[0.1872]	[0.3423]
Total plot area (ha)	1,503	1,416	1,502	1,519	1,425	1,257	1,486	1,593	1,511	1,584
	[0.1471]	[0.2182]	[0.1680]	[0.1995]	[0.1682]	[0.3493]	[0.1512]	[0.1902]	[0.1592]	[0.7097]
Total plot area squared	-204.6	-190.8	-204	-208.3	-183.8	-148.9	-202.6	-214.2	-205.1	-212.3
	[0.6557]	[0.6326]	[0.6610]	[0.6800]	[0.6436]	[0.6396]	[0.6466]	[0.6887]	[0.6306]	[0.4775]
Weather shock rice (=1)	-508.7**	-494.1**	-497.1*	-550.2**	-506.5**	-489.3***	-512.3**	-477.6**	-515.6**	-561.7
	[0.0230]	[0.0290]	[0.0480]	[0.0200]	[0.0150]	[0.0200]	[0.0320]	[0.0120]	[0.0210]	[0.3463]
Weather shock non-rice (=1)	153.8	135.9	152.1	161.9	149.8	127.6	166.0	58.84	168.4	263.2
	[0.5285]	[0.5966]	[0.5540]	[0.4930]	[0.5275]	[0.5646]	[0.5295]	[0.8078]	[0.5205]	[0.3303]
Constant	130.7	75.41	147.0	83.14	138.4	89.36	142.6	24.84	117.5	52.60
	[0.6967]	[0.8108]	[0.6500]	[0.7640]	[0.6376]	[0.7467]	[0.6607]	[0.9359]	[0.7347]	[0.8719]
Local unit x Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	514	514	514	514	514	514	514	514	514	514
R-squared	0.252	0.249	0.252	0.249	0.254	0.249	0.252	0.203	0.253	0.206

Wild bootstrap cluster robust p-values in brackets; Inverse probability weights are used to control for attrition bias (See Table A1 for the probit analysis of non-attrition).
*** p<0.01, ** p<0.05, * p<0.1.
Source by Authors

Table A3-2: Full estimation results of the impact of practice adoption (cont.)

VARIABLES	(11) Rice yield S FE-OLS	(12) Rice yield S FE-IV	(13) Rice yield N FE-OLS	(14) Rice yield N FE-IV	(15) Rice yield S+N FE-OLS	(16) Rice yield S+N FE-IV	(17) Rice yield B FE-OLS	(18) Rice yield B FE-IV	(19) Rice yield L FE-OLS	(20) Rice yield L FE-IV
Full adoption of all 5 key practices (S+N+B+L+TP)	745.5**	765.6	709.2**	1,054	750.6***	775.5	900.8***	1,239	748.4***	504.9
	[0.0110]	[0.3013]	[0.0190]	[0.1281]	[0.0080]	[0.2202]	[0.0020]	[0.1101]	[0.0080]	[0.3594]
Partial adoption of 5 key practices	-40.42	600.7	-130.5	441.5	27.20	682.9	237.2*	773	-14.39	914
	[0.8258]	[0.1972]	[0.6446]	[0.5275]	[0.8919]	[0.1992]	[0.0711]	[0.2102]	[0.9590]	[0.1321]
Household size	168.0	194.4*	170.0	169.4	171.0*	204.0*	176.7	192.7*	169.5	176.3
	[0.1351]	[0.0841]	[0.1231]	[0.1361]	[0.0991]	[0.0691]	[0.1161]	[0.0791]	[0.1331]	[0.1331]
Household size squared	-12.10	-14.38	-12.05	-12.92	-12.37	-15.37*	-12.66	-13.59*	-12.22	-14.18
	[0.1692]	[0.1201]	[0.1632]	[0.1562]	[0.1201]	[0.0841]	[0.1311]	[0.0951]	[0.1602]	[0.1291]
Proportion of known farmers	-6.626	-8.069	-6.445	-7.722	-6.807	-8.954	-6.567	-6.223	-6.747	-4.755
	[0.1882]	[0.1702]	[0.1692]	[0.2062]	[0.1832]	[0.1642]	[0.1842]	[0.2012]	[0.1602]	[0.2322]
Total plot area (ha)	1,488	1,740	1,494	1,482	1,516	1,823	1,530	1,592	1,509	1,198
	[0.1652]	[0.2092]	[0.1542]	[0.1792]	[0.1371]	[0.1712]	[0.1391]	[0.1612]	[0.1421]	[0.1562]
Total plot area squared	-203.4	-224.4	-203.5	-200	-205.7	-231.9	-207.6	-214.5	-206.2	-119.2
	[0.6366]	[0.6647]	[0.6476]	[0.6747]	[0.5986]	[0.6146]	[0.6376]	[0.5546]	[0.5936]	[0.5676]
Weather shock rice (=1)	-507.1**	-535.2***	-505.0**	-512.5**	-508.6**	-505.3***	-528.5**	-573.5**	-507.3**	-612.3***
	[0.0260]	[0.0040]	[0.0250]	[0.0160]	[0.0240]	[0.0040]	[0.0180]	[0.0330]	[0.0290]	[0.0080]
Weather shock non-rice (=1)	158.9	79.72	152.9	146.1	149.7	51.72	180.3	240.4	151.2	336.6
	[0.5095]	[0.7427]	[0.5526]	[0.5806]	[0.5365]	[0.8418]	[0.4985]	[0.4424]	[0.5666]	[0.2713]
Constant	136.5	52.29	118.7	138.2	128.9	85.99	55.34	-114.2	131.1	162.9
	[0.6817]	[0.8278]	[0.7167]	[0.6677]	[0.6767]	[0.7177]	[0.8679]	[0.7427]	[0.6937]	[0.5485]
Local unit x Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	514	514	514	514	514	514	514	514	514	514
R-squared	0.252	0.196	0.253	0.225	0.252	0.211	0.257	0.229	0.252	0.168

Wild bootstrap cluster robust *p*-values in brackets; Inverse probability weights are used to control for attrition bias (See Table A1 for the probit analysis of non-attrition).
*** p<0.01, ** p<0.05, * p<0.1
Source by Authors

Table A3-3: Full estimation results of the impact of practice adoption (cont.)

VARIABLES	(21) Rice yield B+L FE-OLS	(22) Rice yield B+L FE-IV	(23) Rice yield TP FE-OLS	(24) Rice yield TP FE-IV	(25) Rice yield Variety Chupa FE-OLS	(26) Rice yield Variety Chupa FE-IV	(27) Rice yield Variety Mamima FE-OLS	(28) Rice yield Variety Mamima FE-IV	(29) Rice yield Variety Mocuba FE-OLS	(30) Rice yield Variety Mocuba FE-IV
Full adoption of all 5 key practices (S+N+B+L+TP)	814.7***	885.6	744.8***	794.2	743.2**	1,053	738.2**	955.9**	737.2***	1,092
	[0.0050]	[0.1251]	[0.0060]	[0.2362]	[0.0150]	[0.1502]	[0.0100]	[0.0521]	[0.0080]	[0.1692]
Partial adoption of 5 key practices	438.5	1,081	-137.8	1,123	-89.92	849.1	206.5	271.7	73.72	-102.3
	[0.1872]	[0.4515]	[0.5425]	[0.2803]	[0.6466]	[0.2623]	[0.1351]	[0.8108]	[0.7077]	[0.9139]
Household size	168.4	166.4	167.5	187.6*	175.1	119.3	170.0	171.3	172.0*	168.2
	[0.1301]	[0.1301]	[0.1041]	[0.1181]	[0.1011]	[0.4164]	[0.1011]	[0.2202]	[0.1001]	[0.3073]
Household size squared	-12.10	-11.87	-11.84	-15.6	-12.55	-9.396	-12.20	-12.2	-12.45	-11.99
	[0.1602]	[0.1572]	[0.1542]	[0.1622]	[0.1281]	[0.4144]	[0.1562]	[0.1582]	[0.1451]	[0.2513]
Proportion of known farmers	-6.397	-5.915	-6.843	-5.705	-6.590	-8.048	-6.912	-7.077	-6.712	-6.879
	[0.1872]	[0.1692]	[0.1652]	[0.2252]	[0.2122]	[0.1491]	[0.1572]	[0.2503]	[0.1692]	[0.6156]
Total plot area (ha)	1,336	1,098	1,491	1,597	1,513	1,327	1,539	1,483	1,500	1,406
	[0.2022]	[0.2723]	[0.1732]	[0.2062]	[0.1602]	[0.2362]	[0.1532]	[0.4084]	[0.1371]	[0.6136]
Total plot area squared	-164.2	-106.1	-203.2	-215.1	-205.7	-181.8	-213.9	-206.1	-204.4	-188.9
	[0.6446]	[0.5706]	[0.6356]	[0.6627]	[0.6316]	[0.6877]	[0.6406]	[0.4324]	[0.6156]	[0.5075]
Weather shock rice (=1)	-514.5**	-524.3	-511.0**	-490.0**	-499.2**	-585.9**	-494.6**	-478.7	-513.2**	-485.6
	[0.0170]	[0.1041]	[0.0240]	[0.0100]	[0.0210]	[0.0330]	[0.0280]	[0.1562]	[0.0150]	[0.3924]
Weather shock non-rice (=1)	200.7	271.2	162.3	83.47	145.8	213.2	130.4	109.0	160.5	123.7
	[0.4585]	[0.3684]	[0.5295]	[0.7117]	[0.5936]	[0.4815]	[0.6166]	[0.6667]	[0.4835]	[0.7107]
Constant	91.27	38.33	146.4	0.791	127.4	113.8	141.0	100.9	139.8	54.17
	[0.7698]	[0.8749]	[0.6587]	[0.9980]	[0.6907]	[0.7327]	[0.7017]	[0.6897]	[0.6807]	[0.8619]
Local unit x Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	514	514	514	514	514	514	514	514	514	514
R-squared	0.261	0.241	0.252	0.196	0.252	0.190	0.255	0.253	0.252	0.247

Wild bootstrap cluster robust *p*-values in brackets; Inverse probability weights are used to control for attrition bias (See Table A1 for the probit analysis of non-attrition).
*** p<0.01, ** p<0.05, * p<0.1.
Source by Authors

Abstract (in Japanese)

要約

サハラ以南のアフリカにおいて稲作の「緑の革命」を実現するためには、アジアにおいては伝統的に根付いていた基本的な営農技術（種子選別、苗床、圃場の均平化と畦つくり、正条植え）の普及から始めなければならないという議論がある。本研究は、モザンビークの天水地区で実施されたそのような営農技術普及のトレーニングをランダム化比較試験の手法を使い評価した。トレーニングはデモ圃場におけるファーマーフィールドスクール(farmer field schools, FFS)と社会的学習(social learning)を通した農家間普及(farmer-to-farmer extension, F2FE)の手法を用い行われた。もみ米収量への処置意図(intention-to-treat, ITT)効果は、不安定な降雨にもかかわらず、447 – 546 kg/ha（比較対象群の平均収量の 29 – 36%)で、その有意水準は 7 – 8％であった。この結果は、基本営農技術を普及させることで、近代品種や化学肥料といった近代的投入財に頼らずとも収量を増加させることが可能であり、政策的には、金銭的理由や距離的理由で近代的投入財へのアクセスが限られている遠隔地の農家でも生産増加が可能であることを意味している。本研究はまた、基本営農技術の間には補完性があるため基本技術群をパッケージとして採用することが収量増加にとって重要であることも確認した。

キーワード:営農トレーニング、普及システム、技術採用、稲作、緑の革命

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