How does drought-tolerant rice help farmers? Evidence from randomized control trials in eastern India[1]

January 2015

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Abstract

By using data from a randomized control trial (RTC) of 1,680 farmers in eastern India, this paper investigates how a drought-tolerant rice variety, called Sahbhagi Dhan, helps farmers. In the RTC, farmers in treatment villages received 5 kg seeds of Sahbhagi Dhan before Kharif, which is the main agricultural season in India, in 2012 or 2013. The paper finds that Sahbhagi Dhan enabled farmers cultivate crops after Kharif partly because of its short duration. The impact was larger when farmers experienced severe drought in Kharif so that farmers can compensate the crop loss in the season. This helps farmers to become less vulnerable against crops chocks. However, the average yield of Sahbhagi Dhan was found lower than that of other rice varieties under both normal and drought conditions. The findings in this paper recommends that Sahbhagi Dhan to be promoted in areas where the potential for double cropping is under-exploited.

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[1] This paper is an output of a joint project between the International Rice Research Institute and University of California at Berkeley. The Berkeley team is led by Dr. Alain de Janvery and Dr. Elisabeth Sadoulet. The funding for the study was obtained from the Agricultural Technology Adoption Initiative (ATAI) project and the International Initiative for Impact Evaluation (3ie).

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1. Introduction

The largest number of food insecure people live in South Asia, where about 300 million people are undernourished (FAO et al., 2012). There is a concern that climate change will worsen the situation by negatively affecting agricultural production in the region (Tubiello et al., 2007, Lobell et al., 2011). Studies that use a range of scenarios show that higher temperature will lead to lower rice yields as a result of shorter growing periods (IPCC, 2014). Wassmann et al. (2010) conclude that current temperatures are already approaching critical levels during susceptible stages of plant growth in some parts of Asia. Effective adaptation of cropping technologies and practices that mitigate the negative impact of climate change is imperative to enhance food security and sustainable livelihoods in developing countries like India.

Extremely high temperature during vegetative growth of rice reduces tiller number and plant height (Yoshida, 1981). Exposure to high temperature during rice flowering can greatly reduce pollen viability which leads to yield loss (Matsui et al., 2000). To reduce yield loss due to drought, drought-tolerant rice varieties have been developed, and Sahbhagi Dhan is one of them. Sahbhagi Dhan is tolerant against drought partly because it matures early, thus has a short growth duration, and avoids high temperature (Dar et al., 2014). The short growth duration of the variety can allow farmers to cultivate another crop immediately after the harvest of the variety. In Bangladesh, for instance, cultivation of early maturing rice varieties in the main agricultural season allowed farmers to obtain higher yields by planting rice early and receiving high income by selling rice early while the rice price was high (Malabayabas et al., 2014). Diversified income source makes farmer resilient against negative income shocks. Few studies, however, evaluated the performance of Shabhagi Dhan among farmers. Agronomical studies, for instance, only evaluate the performance of crop growth but have not investigated how farmers change cropping practices after adopting Sahbhagi Dhan.

Randomized control trials (RCTs) have been used to assess economic impacts of new agricultural technologies. A recent study by Dar et al. (2013) used a RTC to evaluate the impact of cultivating a submergence tolerant rice variety in eastern India. In this study, we use a RCT to evaluate the performance of Sahbhagi Dhan by providing Sahbhagi Dhan seeds to randomly farmers in treatment villages either in 2012 or 2013. The treatment farmers were subsequently interviewed by our enumerators along with the same number of randomly selected control households who lived in near-by villages. The 2012 RCT involved 420 farmers, and the study area was significantly expanded in 2013 to cover different drought conditions and added 1,270 sample farmers. In the following sections of the paper, we estimate the impact of cultivating Sahbhagi Dhan on rice yield and the probability of cultivating another crop after harvesting Sahbhagi Dhan.

The paper is organized as follows. Section 2 provides background information about the needs for drought-tolerant rice varieties and the development and distribution of Sahbhagi Dhan in India. Section 3 explains how we conducted RTCs and describes the data used in this paper. Comparative statistics were shown in Section 4, which is followed by the results from regression analyses in Section 5. Conclusions are presented in Section 6.

2. Drought-tolerant Rice Variety: Needs, Development, and Distribution

2.1 Climate Change

Under a plausible scenario, climate change is likely to impact the food production around the world and in India. Climate change is expected to affect yields (Tubiello et al, 2007; Lobell et al., 2011). Recent findings from IPCC shows that with or without adaptation, negative impacts on average yields will occur from 2030s with median yield impacts of 0 to -2% per decade projected for the rest of the century. Many models that use a range of scenarios show that higher temperature will lead to lower rice yields as a result of shorter growing period (IPCC, 2014). With rise in temperature, the process of rice development accelerates and reduces the duration of growth. As a result, rural poverty in parts of Asia could be exacerbated due to impacts on the rice crop and increase in food prices and the cost of living (Hertel et al., 2010). Effective adaptation of cropping technologies and practices that mitigate the negative impact of climate change would be critical in enhancing food security and sustainable livelihoods, especially in developing countries like India. Livelihood in developing countries depending on agriculture are particularly vulnerable to changes in the mean and variability of the climate, and the need is highlighted in many studies (IPCC, 2014). Switching to more drought or submergence tolerant crop species or varieties is an important adaptation strategy with a diverse portfolio of livelihood responses to climatic stress. In the portfolio of common on farm and non-farm livelihood adaptation strategies, changing crop variety that are resistant to climate stress is among the most cited adaptation measure (Westengen et al., 2014).

2.2 Current Use of Rice Varieties in Eastern India

Since the Asian Green Revolution, modern rice varieties have helped farmers increase rice yields (David and Otsuka, 1994; Estudillo and Otsuka, 2013) and reduced poverty (Otsuka, Estudillo, and Sawada, 2008). However, the impact of the Asian Green Revolution has been limited for rainfed areas, particularly those affected by flash flooding and drought (Fan and Hazell, 2001; Evenson and Gollin, 2003). Indeed, despite the large number of rice varieties released in the past decades, farmers in eastern India use early-generation high-yielding varieties, which were developed more than 20 to 30 years ago. By using a survey of more than 5,800 rice farmers across four states in eastern India, Yamano et al. (2014) estimated areas under rice varieties in the region. The most popular rice variety, called Swarna, is estimated to occupy 4.6 million hectares or 31 % of the total rice area in the study area (Appendix Table A1). Because the second most popular variety, is estimated to cover only 3.7 % of the total rice area, the popularity of Swarna is unmistakable. Swarna was released in 1979, and all of the top ten varieties, except two, were released before 2000. The area-weighted age of rice varieties is about 25 years old, and this is very high compared with that in other developing countries, such as the Philippines (Launio et al., 2008).

Yamano et al. (2014) also found a submergence-tolerant rice variety called, Swarna-Sub1, which was released in 2009 in India. The total area under Swarna-Sub1 is about 376,500 ha, which accounts for 2.6% of the total rice area and places Swarna-Sub1 as the seventh most popular rice variety in terms of the area coverage. Regarding the number of users, Swarna-Sub1 is the fifth popular rice variety: the estimated number of farmers who cultivated it in 2013 is 704,000 farmers. Only a small number of farmers were found cultivating Sahbhagi Dhan in Kharif 2013.

3. Randomized Control Trial: Study design and balancing test

In May/June 2012, we conducted a randomized control trial (RTC) by randomly selecting 128 treatments and 128 control villages in one district in Odisha and two districts in West Bengal. In each treatment village, five farmers were randomly chosen to receive a mini-kit with 5 kg of Sahbhagi Dhan seeds, accompanied by a brochure with instructions for cultivation. In order to ensure compliance with the randomization, the enumerators had to create a list of 100 households, with village officers, in a village and make a phone call to an officer in New Delhi to obtain five random numbers to select treatment farmers. In the control villages, five farmers were selected according to the same protocol. The 2012 sample thus consisted of 256 villages and five farmers per village, who were all interviewed in multiple surveys.

In 2013, we expanded the study areas by (1) taking 79 sample villages out of the 256 sample villages in the 2012 RTC and (2) adding 252 villages across six more districts in Odisha and Jharkhand (Figure 1). The study area was expanded to capture a larger variation in drought conditions across different ecological zones since drought conditions tend to have less variation in near-by areas. For the additional samples in 2013, we used the following sampling procedure:

1. Purposely selected nine districts that are drought-prone.
2. Randomly selected blocks in each sample district.
3. In each block, a rainfall station was identified, and nearby villages were selected.[2] Out of the listed villages, four villages were randomly chosen, and five households were randomly chosen in each selected village. We followed the same protocol used in 2012 to randomly

[2] From the rainfall stations, daily rainfall data were collected to identify drought conditions. But for the analysis of this paper, the rainfall information was unavailable.

select five households. Out of the four villages, two villages were selected as treatment villages, and the remaining villages were selected as control villages.

After the household selection, we conducted a household survey in March to May 2013. To avoid any possible influence on survey results, respondents were not informed about their treatment status at the time of the survey. Only several weeks after the household survey did treatment households receive Sahbhagi Dhan mini-kits. In a five month period of April – August 2014, we conducted a follow-up survey of the same sample households. Table 1 describes the distribution of sample households across three states.

The total number of villages is 336: 79 villages from the 2012 sample and an additional 257 villages chosen in 2013. The total number of sample households is 1,680: 420 farmers from the 2012 survey and 1,260 farmers chosen in 2013. Half of the sample villages and half of the sample households are in the treatment group. In Figure 1, the 2012 sample villages are marked by blue, while the 2013 sample villages are marked by red. The markers of the treatment villages are triangles, while the markers of the control villages are circles. Out of 1,680 households, 1,645 households were re-interviewed again in 2014. In Figure 1, it is clear that there are four clusters of sample villages. These clusters are located in drought-prone areas and distanced from each other. Thus, it is expected that sample villages will be exposed to different drought conditions in a given year, providing opportunities for us to identify the impacts of adopting Sahbhagi Dhan under different levels of drought.

Balancing Test

To investigate whether the treatment and control households were randomly selected, we compared the basic household characteristics of the two groups (Table 2). After comparing means and estimating a Probit model, we found no significant differences in the variables presented in the table. For instance, the average age of the household heads is about 49 years old in the two groups, and the difference is 1.3 years. The t-test confirms that the difference is not statistically significant. We found no difference in household size and farm size (in ha) also. In the control group, the proportion of scheduled caste is slightly higher than that of the treatment group. However, we found that this is not statistically significant.

4. Descriptive Analyses

4.1 Rice Yield

Popular rice varieties cultivated by our sample farmers are listed in Table 3. Among control households of the 2012 samples, Swarna is the most popular rice variety, occupying more than 30 % of the areas under rice, followed by hybrid (which combines all hybrid varieties) and Lalat. Lalat is a modern rice variety released in 1988. Detailed information of Lalat and other varieties are presented in Appendix Table A-2. Before the planting season of Kharif 2012, the 2012 treatment households received Sahbhagi Dhan seeds. The area under Sahbhagi Dhan was 15.2 % in 2012. By comparing the land allocation of the 2012 control group, it appears that the 2012 treatment farmers replaced Swarna and Lalat with Sahbhagi Dhan. In 2013, however, the areas of Swarna and has increased to 31.5 % of the total area, which is comparable to the area under Swarna among the control group.

Because the 2013 treatment farmers received Sahbhagi Dhan seeds in 2013, they did not cultivate it in 2012. Thus, we can directly see how Sahbhagi Dhan changes the area allocation across rice varieties before and after receiving Sahbhagi Dhan. Before receiving Sahbhagi Dhan, the most popular rice variety was Hybrid among the 2013 treatment households, occupying 14.6 % of the total rice area in Kharif 2012. Swarna was the second most popular (12.1 %), followed by Lalat (9.4 %) and IR64 (8.9 %). After receiving Sahbhagi Shan, the areas under Hybrid, Lalat, and other varieties have declined significantly, while the area under Swarna did not change significantly. As we will show later in this paper, Hybrid varieties and Lalat have short growth duration. Thus, it seems that farmers replaced short duration rice varieties with Sahbhagi Dhan, which is also a short duration rice variety.

Next, we present the average rice yields of the treatment and control farmers. Among the 2012 treatment farmers, the average rice yield was about 2.6 tons per ha in 2012 but declined to 2.31 tons per ha in 2013, while the average yield among the control households remained around 2.2 to 2.3 tons per ha. Among the 2012 treatment households, the average yield of Sahbhagi Dhan was 2.8 tons per ha in 2012. This was about 10 % lower than that of the other varieties among the treatment farmers. In 2013, the rice yields declined for both Sahbhagi Dhan and other rice varieties, although the decline was larger for Sahbhagi Dhan: the average yield of Sahbhagi Dhan declined by 0.5 tons per ha, to 2.3 tons per ha, among the treatment farmers between 2012 and 2013. The average yield of the other variables also declined by about 0.3 tons per ha during the same period. Among the 2012 control farmers, the yield remained around 2.9 tons per ha.

The 2013 sample farmers have lower yields than the 2012 sample farmers. For instance, the average yield among the 2013 control farmers in 2012 was about 2.2 tons per ha, while that of the 2012 control farmers was about 3.0 tons per ha. This is as expected because drought-prone areas were purposefully selected for area expansions. What is important is that the comparison between the control and treatment farmers before the RCT intervention. In 2012, the average yield of the 2013 treatment farmers is 2.3 tons per ha, which is not statistically different of that of the control farmers. This again confirms that the selection of the treatment farmers was implemented properly.

In 2013, the treatment farmers of this group received Sahbhagi Dhan seeds. The average yield of Sahbhagi Dhan was only 1.5 tons per ha, which is lower by more than 0.9 tons per ha than that of the other rice varieties grown by the same farmers in the same year. Even among the 2012 treatment farmers, the average yield of Sahbhagi Dhan about lower than that of the other rice varieties by 0.3 and 0.6 tons per ha, respectively, in 2012 and 2013.

Constructing a Drought Indicator

To investigate if Sahbhagi Dhan performs better under drought conditions, we have asked respondents to classified if they experienced mild, severe, and very severe drought along the rice growth duration during the Kharif seasons in the surveys. The growth duration was divided into five: sowing to transplanting period, early to tillering period, panicle initiation period, heading to flowering period, and harvesting period. Because exposure to extremely high temperature during flowering period has been found to reduce rice yield (Matsui et al., 2000), we have decided to focus on the drought condition during the heading to flowering period. The drought conditions during the harvest period also affect farmers' decisions on cultivating crops in the following agricultural season, called Rabi in India. Because these two periods are important both on rice yields and cultivation of Rabi crops, and because the drought conditions of the two periods are highly correlated, we have decided to combine the two periods.

The drought perceptions may very among farmers in one area, although they are exposed to the same weather conditions. Thus, instead of using drought perception at the individual level, we have aggregated the individual perceptions to the block level because four villages were selected around a block level rainfall stations. Therefore, at the block level, four villages (two treatment and two control villages) should be exposed to the same drought conditions. However, because Sahbhagi Dhan is an early maturing rice varieties, their rice growth periods may be different from those of the control farmers. For instance, what the treatment farmers describe as a harvesting period could still be a flowering period for the control farmers. Thus, we only use the drought perception of the control farmers and aggregated up to the block level and apply it to both control and treatment farmers. As a result, we have created a drought index which is the proportion of (control) farmers who experienced severe drought during the heading to harvesting period.

Rice Yield under Drought

To examine the relationship between the rice yield and the drought condition, we have the Karnel-weighted local polynomial smoothing technique and plotted the smoothed lines in Figure 2 for Sahbhagi Dhan and the other varieties.[3] In Figure 2, we find that the yield of Sahbhagi Dhan is lower than that of the other varieties even under drought conditions, although the difference

[3] The graph was created by using STATA.

between the two groups shrinks as the proportion of farmers who experienced drought becomes higher and close to 1. The yield of the other varieties remain flat above 2.5 tons per ha while the proportion of farmers with severe drought is below 0.4. As the proportion increases beyond 0.4 and reaches 1, the yield declines quickly to 0.5 tons per ha. The yield of Sahbhagi Dhan is about 0.3 to 0.5 ton per ha lower than the yield of the other varieties while the proportion of farmers with severe drought is below 0.4. However, the yield declines to 0.5 tons per ha as the proportion of the farmers reaches 1, and the difference gap between the yields of Sahbhagi Dhan and the other varieties disappears.

4.2 Cultivation of Rabi Crop after Kharif season

One major advantage of Sahbhagi Dhan is its short growth duration. In Table 5, we show the average length of the growth duration in weeks, the typical planting week, and the typical harvesting week during Kharif 2013 for major rice varieties. The data are sorted by the length of growth duration of popular rice varieties. Sahbhagi Dhan has the shortest duration of 17 weeks, which corresponds to 107 to 119 days.[4] Next is Lalat with 17.7 weeks. The average growth durations of Hybrid, IR64, Swarna, and other minor rice varieties are longer than 20 weeks. The average growth duration of Swarna, the most popular rice varieties in the study region, is about 21 weeks. Thus, the difference in the length of growth duration between Swarna and Sahbhagi Dhan is about 4 weeks, about a month. In general, rice varieties with a longer duration lengths has a higher yield. The typical planting week for Sahbhagi Dhan was the third week of July, 2013, in

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[4] Because we asked respondents to identify the planting and harvesting week for each plot, the actual duration length in days is less (by up to 14 days) than the number of days of the duration in weeks, i.e., weeks times 7 days.

the survey areas in Eastern India. After 17 weeks, it was harvested during the first week of November.

From Table 5, it is clear that during the second and third weeks of July, most of the rice varieties were planted. Then, Sahbhagi Dhan and Lalat were harvested during the first and second weeks of November, making the rice fields available for next crops. In the last column of the table, we show the proportion of plots with second crops, which was mostly Rabi crops but included vegetables which were grown in between Kharif and Rabi seasons, and names of major second crops. After the harvest of Sahbhagi Dhan, about 20 % of the plots were used for growing a second crop. The list of second crops after Sahbhagi Dhan includes wheat, pulses, and vegetables. Early sowing of wheat is considered to increase its yield because it can avoid the terminal heat of its harvesting time in next spring. Vegetables were mostly planted in between Kharif and Rabi seasons and provide additional income to rice farmers. Although Swarna is the most popular rice variety, after Swarna, only 3.0 % of its plots were allocated to second crops.

To investigate more in detail, we have calculated percentage of plots with second crops for treatment and control households for both 2012 and 2013 in Table 6. In Table 6, among both groups, the percentage of plots with second crops increased from 2012 to 2013. However, among the 2012 samples, cultivation of second crops is very limited. For instance, less than 5 percent of the plots have any second crops among the treatment households in both 2012 and 2013. To cultivate crops during Rabi season, farmers need to have some access to water through irrigation. Our survey data indicate that less than 5 percent of the plots of the 2012 sample households have access to underground water irrigation through wells, while about 10 percent of the plots of the 2013 sample households have access to underground water irrigation.

Among the 2013 sample households, we find that the percentage of plots with second crops increases by 8.5 percentage points, from 15.5 percent to 24 percent, on plots that the treatment farmers cultivated Sahbhagi Dhan in 2013. This is a before-after indicator on the same plots. On the other plots where other rice varieties were grown of both the treatment and control farmers, the percentage of plots with second crops also increased by 5 5 to 5.6 percentage points. Thus, it seems there is a upward trend in cultivating second crops in the areas of the 2013 samples. However, it seems that the impact is larger after cultivation of Sahbhagi Dhan.

To see which crops that they cultivate after Sahbhagi Dhan, we present list of crops that farmers cultivated after Kharif season in Table 7. From 2012 to 2013, the total cultivation areas expanded from 52 ha to 75 ha among the 2013 treatment farmers, while it increased only by 8.8 ha among the control farmers. Among the 2013 treatment farmers, pulse has expanded areas significantly. Area under vegetables also increased, although the percentage of the area share remains only about 2 %.

To examine how drought in Kharif affects cultivation of second crops, we have plotted the probability of cultivating second crops against the level of drought in Figures 3 and 4. We created the graphs for the 2012 and 2013 samples separately, because the results in Tables 6 and 7 clearly show that few farmers cultivate second crops in the 2012 sample areas. Figure 3 confirms the expectation.

Figure 4 shows an interesting result. The probability of cultivating second crops after a Kharif season depends on the level of drought during the Kharif season. As the drought in Kharif season becomes severe, affecting more than half of farmers, the probability of cultivating second corps increases. This is probably farmers try to compensate the crop losses due to drought by cultivating second crops immediately after the harvest of rice. The probability quickly increases on Sahbhagi Dhan plots. Because the harvest of Sahbhagi Dhan is early, farmers can quickly shift to cultivation of second crops under drought. Under drought conditions, rice prices also increases. This may help Sahbhagi Dhan farmers to fetch high prices by harvesting Sahbhagi Dhan early, as was the case of early maturing rice varieties in Bangladesh (Malabayabas et al., 2014).

From the descriptive analyses in this section, it appears that Sahbhagi Dhan has lower yields than other rice varieties but allow farmers to cultivate second crops after Kharif season. However, the analyses in this section do not control for other factors that affect rice yield. Although randomized control trials are designed to control for farmer characteristics by selecting treatment farmers randomly, treatment farmers can still control production conditions for Sahbhagi Dhan. In particular, farmers can chose plots for different varieties, including Sahbhagi Dhan, and their decisions might have affected the results both on yields and cultivation of second crops. Fortunately, with the panel data, we can control for the plot characteristics by estimating the plot level fixed effects model. In the next section, we will describe our estimation models.

5. Estimation Models

In the following section, we estimate two models. The first is the rice yield model, and the second is the determinants of cultivating second crops. Both models are estimated at the plot level. With panel data, we estimate the both models with the plot level fixed effects. This helps us remove bias in the regression results caused by unobserved plot characteristics. Even randomly selected treatment farmers can select plots for Sahbhagi Dhan. If the treatment farmers choose better plots for Sahbhagi Dhan, the estimation results will have upward bias, and the opposite is also possible.

$$Y_{sijt} = \alpha + \beta_1 S_{sijt} + \beta_2 D_{jt} + \beta_3 D_{jt} S_{sijt} + \cdots + e_{ijt}$$

where Y_{sijt} is rice yield (kgs per ha) of plot s of farmer i of block j at time t; S_{sijt} is a Sahbhagi Dhan dummy variable which takes one if Sahbhagi Dhan is cultivated on plot s of farmer i of block j at time t; D_{jt} is an indicator of drought in block j at time t; and $D_{jt}S_{sijt}$ is the interaction term between S_{sijt} and D_{jt}. The estimation model also include other variables of household characteristics. On the second model, the dependent variable is a dummy variable which takes one if second crops are cultivated on the same plot. Because the dependent variable is a dummy variable, the model becomes a liner probability model with the plot level fixed effects. We will compare the basic model with the results from Probit if the results in linear probability model are robust.

Because Sahbhagi Dhan seeds were distributed to randomly selected treatment households, the Sahbhagi Dhan dummy variable may not be correlated with unobserved characteristics at the household level. But as mentioned before, it could be correlated with unobserved characteristics of plots because the treatment farmers can decide which plots they cultivate Sahbhagi Dhan. With the panel data, we have two observations across years. During the second survey in 2014, asking about 2013 Kharif production, special care was taken at the time of surveys to clearly identify the plots which were mentioned in the 2012 survey. Because the interviews were conducted by using a computer assisted personal interview program,[5] the enumerators could see plot information

[5] We use a software called *Surveybe*.

collected in the previous survey on screen. By describing the name, size, tenure status, and plot type, enumerators could identify the plots with the respondent making sure to collect information of Kharif 2013 production information of the same plots.

6. Results

6.1 Yield Model

The first model in Table 8 is OLS model with block dummies (Column 1). We included block dummies because the first sampling level is at the block level, as we explained in Section 3. The estimated coefficient remains significant even when estimated the plot level fixed effects model (Columns 2), indicating that the yield of Sahbhagi Dhan is lower than that other varieties by 0.3 to 0.4 tons per ha. Drought, measure by the proportion of farmers experienced severe drought during the heading and harvesting period in a Kharif season, significantly reduces rice yield. The magnitude of the estimated coefficient suggests that the yield declines by 1.3 tons per ha if the drought is severe enough for all farmers experience severe drought. The estimated coefficient of the interaction term between the Sahbhagi Dhan dummy and the drought indicator, is not significant suggesting that Sahbhagi Dhan does not mitigate the negative impact of drought. The estimation results are consistent with the graphical analysis in Figure 2.

The estimated coefficients of the other variables are as expected. The plot size has a reverse correlation with the yield: the yield declines by 0.7 tons per ha as the plot size increases by 1 ha. When farmers use seed broadcasting, instead of transplanting of seedlings, the rice yield declines by about half a ton per ha. This may not reduce profit, however, because farmers can reduce labor costs as they switch to broadcasting from transplanting. In drought prone areas where production risks are high, farmers may want to avoid spending on labor in the early stage of the agricultural season. The access to irrigation, both underground and surface water, the rice yield is higher by more than 0.2 tons per ha. Low-land plots, which are located near irrigation facility, have higher yields on middle plots, while up-land plots have lower yields. And finally, scheduled caste and tribe farmers have a significantly lower yield than farmers in general caste groups.

6.2 Cultivation of Rabi Crops

As we divided the samples for Figures 3 and 4, we estimated the second crop cultivation model for the 2012 and 2013 samples separately. The first model is a Probit model with block dummies, in Column 1, as in the first model in the previous table. The estimated coefficient of Sahbhagi Dhan dummy indicates that the probability of cultivating a second crop after Kharif season increases by 3.1 percentage points when farmers cultivate Sahbhagi Dhan. The size of the estimated coefficient remains close at 3.3 when we estimate the linear probability model with plot level fixed effects model.

The drought indicator has a large impact on the probability of cultivating second crops. The size of the estimated coefficient indicate that the probability of cultivating second crops increases by 15 percentage points if all farmers in a block experienced severe drought. Because such a severe drought will cause a significant crop loss on rice, farmers may feel it is necessary to compensate the crop loss by cultivating second crops after the Kharif season. As we find in Figure 3, the impact of the severe drought on the probability of cultivating second crops is higher on

Sahbhagi Dhan plots. This is probably because the variety has a short growth duration and allows farmers to cultivate second crops right after the harvest of Sahbhagi Dhan under severe drought. The estimated coefficient of the interaction term between the drought indicator and the Sahbhagi Dhan dummy suggests that the probability of cultivating second crops increase by about 15 percentage points on Sahbhagi Dhan plots when all farmers experienced severe drought.

Among the other variables included in the estimation model, irrigation dummies have large coefficients. The probability of cultivating second crops increases by about 20 percentage points if farmers have access to either underground or surface water irrigation. The results are consistent with our expectations because farmers will have difficulties cultivating crops after Kharif season if they do not have access to irrigation.

7. Conclusions

To reduce yield loss due to drought, drought-tolerant rice varieties have been developed, and Sahbhagi Dhan is one of them. Few studies, however, evaluated the performance of Shabhagi Dhan among farmers. Thus, we have used a RCT to evaluate the performance of Sahbhagi Dhan by providing Sahbhagi Dhan seeds to randomly farmers in treatment villages either in 2012 or 2013. To measure the impact of drought on rice production, we have created a drought index which is the proportion of farmers experienced severe drought during the heading and harvesting period in a Kharif season. The results in this paper clearly shows that the drought measure by the index significantly reduces rice yield. The magnitude of the estimated coefficient suggests that the yield declines by 1.3 tons per ha if the drought is severe enough for all farmers experience severe drought.

Regarding the yield of Sahbhagi Dhan, we find that the yield of Sahbhagi Dhan is lower than that other varieties by 0.3 to 0.4 tons per ha. We find little evidence that Sahbhagi Dhan is more tolerant against drought than other rice varieties.

Exposure to high temperature during rice flowering can greatly reduce pollen viability which leads to yield loss. Because Sahbhagi Dhan is an early maturing rice variety, it starts flowering earlier than other varieties and becomes vulnerable to high temperature at different timing than other rice varieties, especially late maturing varieties. This makes Sahbhagi Dhan drought tolerant when high temperature occurs after Sahbhagi Dhan completes its flowering period but other varieties enter their flowering periods. In our study, the timing of high temperature in 2012 and 2013 Kharif seasons may not have been favorable for Sahbhagi Dhan. It might be premature to draw conclusion on the variety and need to continue monitoring the performance of the variety.

The short duration of Sahbhagi Dhan helps farmers to cultivate crops after the main agricultural season, Kharif, in India. The results in this paper indicate that the probability of producing second crops after Kharif is higher by 3 percentage points on Shahbhagi Dhan plots than other plots. The results also show that the probability of cultivating second crops is higher when farmers experience drought in Kharif, and the probability becomes even higher on Sahbhagi Dhan plots. After drought, farmers may feel needs to compensate the crop loss due to drought by cultivating more crops after the season. But we only find this benefit in areas where farmers can cultivate crops after Kharif. In areas where it is possible to produce double crops.

The findings in this paper suggest targeting strategies of Sahbhagi Dhan. Based on findings on this paper, the main benefit of Sahbhagi Dhan appears to be the short growth duration. This helps farmers where they can produce crops after Kharif. Thus, the variety should be promoted in areas where the potential for producing crops after Kharif is high. This will help farmers become less vulnerable against drought and other shocks during Kharif by diversifying income sources. Experiments in farmer fields are different from agronomical experiments in research stations. Although we do not observe its drought tolerance in this paper, it can become under certain drought conditions. The drought tolerance of Sahbhagi Dhan continues to be monitored among farmers.

Reference

Dar, M.H., S. Singh, U.S. Singh, N.W. Zaidi, and A.M. Ismail (2014). Stress Tolerant Rice Varieties: Making Headway in India, *SATSA Mukhapatra – Annual Technical Issue*, 18: 1- 14.

Dar, M. H.;Janvry, A. de.;Emerick, K.;Raitzer, D.;Sadoulet, E. 2013. Flood-tolerant rice reduces yield variability and raises expected yield, differentially benefitting socially disadvantaged groups. *Scientific Report,* 3 (3315): 1-8.

David, C.C., and K. Otsuka (1994). *Modern Rice Technology and Income Distribution in Asia,* Lynne Rienner, Boulder.

Dawe, D., S. Pandey, and A. Nelson (2010). Emerging trends and spatial patterns of rice production, in: Pandey S, Byerlee D, Dawe D, Dobermann A, Mohanty S, Rozelle S, Hardy B, editors. *Rice in the global economy: strategic research and policy issues for food security*. Los Baños (Philippines): International Rice Research Institute. p 15-35.

Estudillo, J.P., and K. Otsuka (2013). Lessons from the Asian Green Revolution in Rice, in Otsuka and Larson (eds.), *An African Green Revolution: Finding Ways to Boost Productivity on Small Farms*, Springer.

Evenson, R., and d. Gollin (2003). Assessing the impact of the green revolution, 1960 to 2000, *Science*, 300: 758-762.

Fan, S., and P. Hazell (2001). Returns to public investments in the less-favored areas of India and China, *American Journal of Agricultural Economics*, 83: 1217-1222.

FAO, WFP, and IFAD, 2012: The state of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to Accelerate Reduction of Hunger and malnutrition. FAO, Rome

Foley, J.A. et al. (2011) Solutions for a cultivated planet, *Nature*, 478, 337-342

Godfray, H. C. J. et al. (2010) Food Security: the challenge of feeding 9 billion people, *Science* 327, 812-818.

Hertel, T.W., M.B. Burke, and D.B. Lobell (2010). The poverty implications of climate-induced crop yield changes by 2030, *Global Environmental Change*, 20: 577–585

IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers.

Launio, C.C., G.O. Redondo, J.C. Beltran, and Y. Morooka (2008). “Adoption and Spatial Diversity of Later Generation Modern Rice Varieties in the Philippines,” Agronomy Journal, 100 (5): 1380 – 1389.

Lobell, B., W. Schlenker, and R. J. Costa (2011). Climate Trends and Global Crop Production since 1980, *Science*: 333 (6042), 616-620.

Malabayabas, A.J.B., K. Kajisa, M.A. Mazid, F.G. Palis, and D.E. Johnson (2014). Impacts of direct-seeded and early-maturing varieties of rice on mitigating seasonal hunger for farming communities in northwest Bangladesh, *International Journal of Agricultural Sustainability*.

Matsui, T., K. Omasa, and T. Horie. 2000. High temperature at flowering inhibits swelling of pollen grains, a driving force for the dehiscence in rice (Oryza sativa L.), *Plant Prod. Sci.*, 3: 430-434.

Otsuka, K., J.P. Estudillo, and Y. Sawada, eds. (2008). *Rural Poverty and Income Dynamics in Asia and Africa*, Routledge.

Tubiello, F.N., J.-F. Soussana, S.M. Howden, and W. Easterling, 2007: Crop and pasture response to climate change. *Proc. Natl. Acad. Sci.*, 104, 19686-19690.

Wassmann, R., et al. (2010). Rice and Global Climate Change, in: Pandey S, Byerlee D, Dawe D, Dobermann A, Mohanty S, Rozelle S, Hardy B, editors. *Rice in the global economy: strategic research and policy issues for food security*. Los Baños (Philippines): International Rice Research Institute, p. 15-35.

Westengen T. Ola and Brysting K. Anne (2014) , Crop adaptation to climate change in the semi-arid zone in Tanzania: the role of genetic resources and seed systems, Agriculture & Food Security 2014, 3:3

Yamano, T., A. Panda, G. Ishika, M. Mehar, and M.L. Malabayabasu (2014). Rice Monitoring Survey 2014 in India, mimeo, International Rice Research Institute.

Yoshida, S. (1981). *Fundamentals of rice crop science*, International Rice Research Institute, Los Banos, the Philippines.

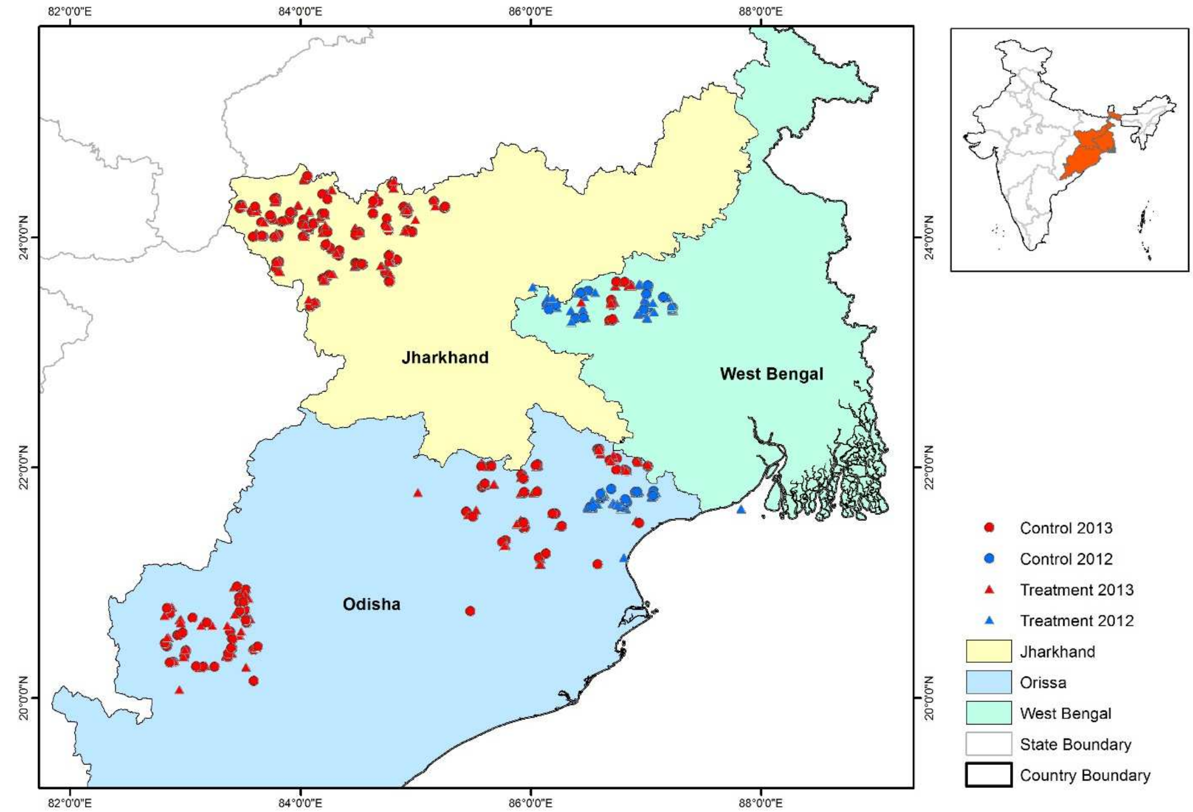

Figure 1. Map of treatment and control villages

Note: Blue markers indicate locations of 2012 sample villages. Farmers in the 2012 treatment villages received 5kg Sahbhagi Dhan mini-kits before the Kharif 2012 season started. Farmers in the 2013 treatment villages received the mini-kits before the Kharif 2013 season started.

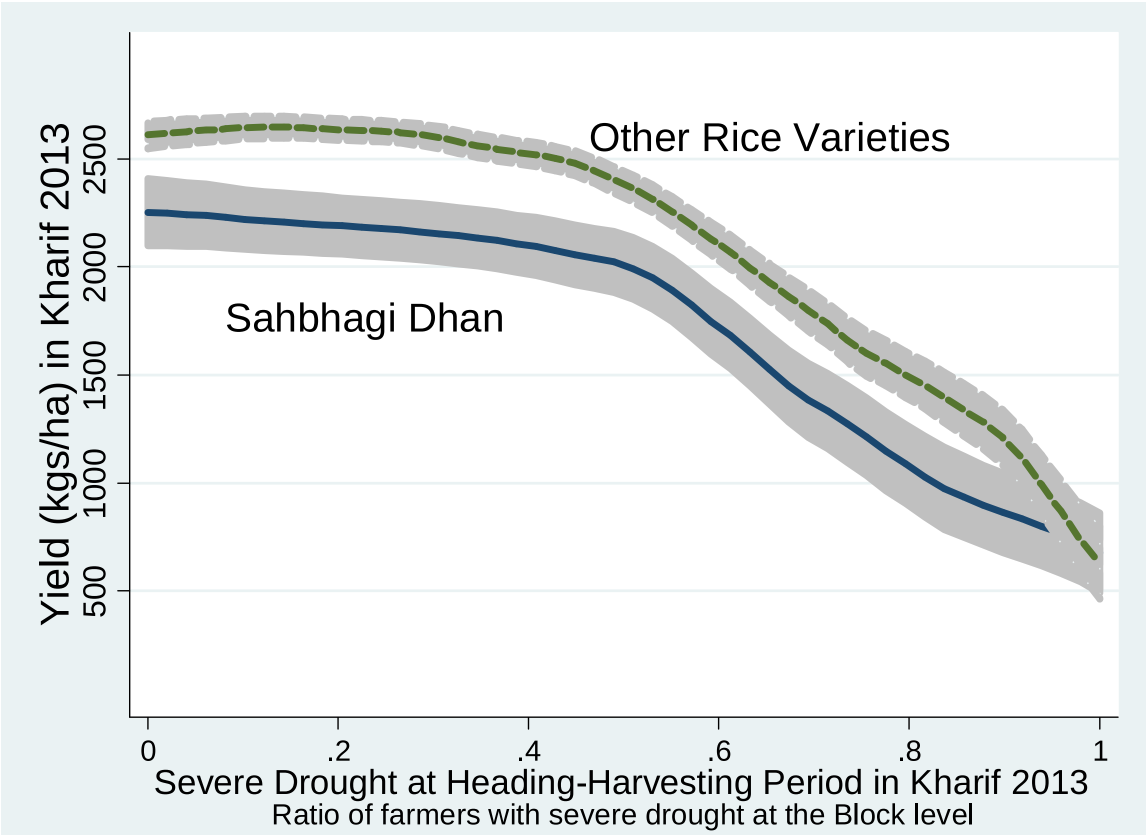

Figure 2. Rice Yield and Severe Drought during Heading–Harvesting period in kharif 2013 at the Plot Level

Note: The level of drought at the heading-harvesting was measured by the proportion of control village farmers who claimed that they experienced severe drought during the rice crop heading and harvesting period of the Kharif 2013 season.

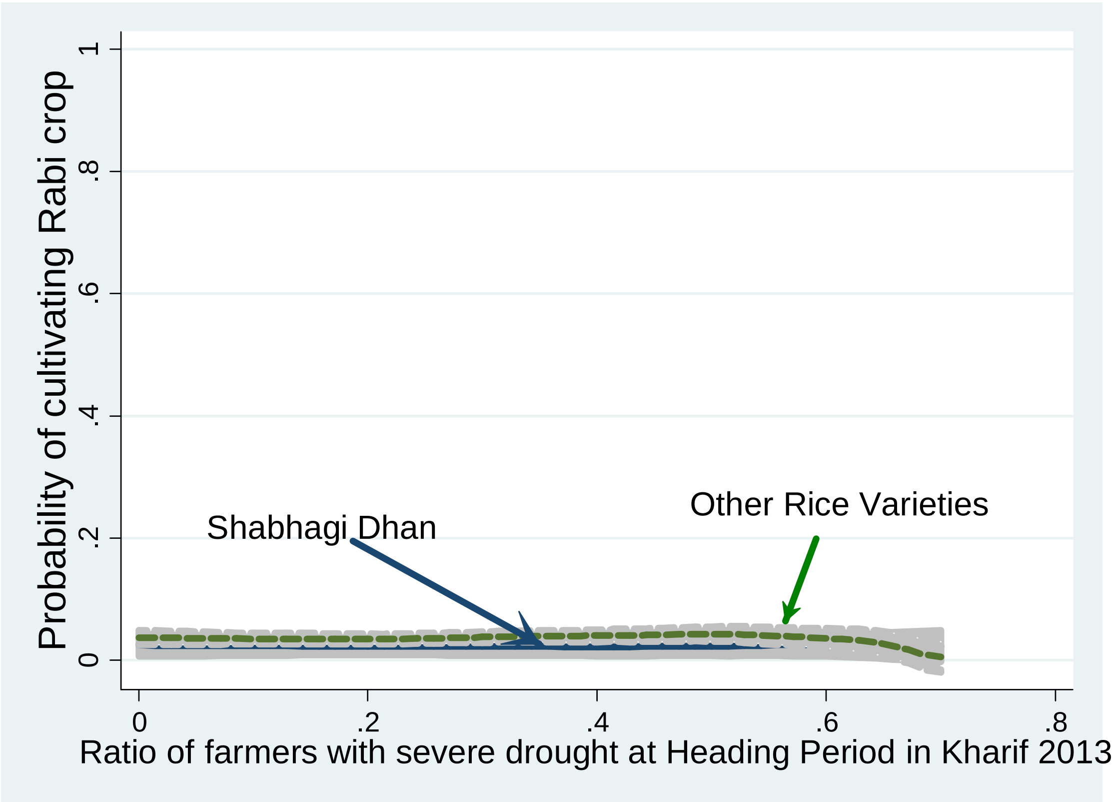

Figure 3. Probability of cultivating a Rabi crop and Severe Drought during Heading–Harvesting period in kharif 2013 at the Plot Level: Among 2012 Sample Farmers

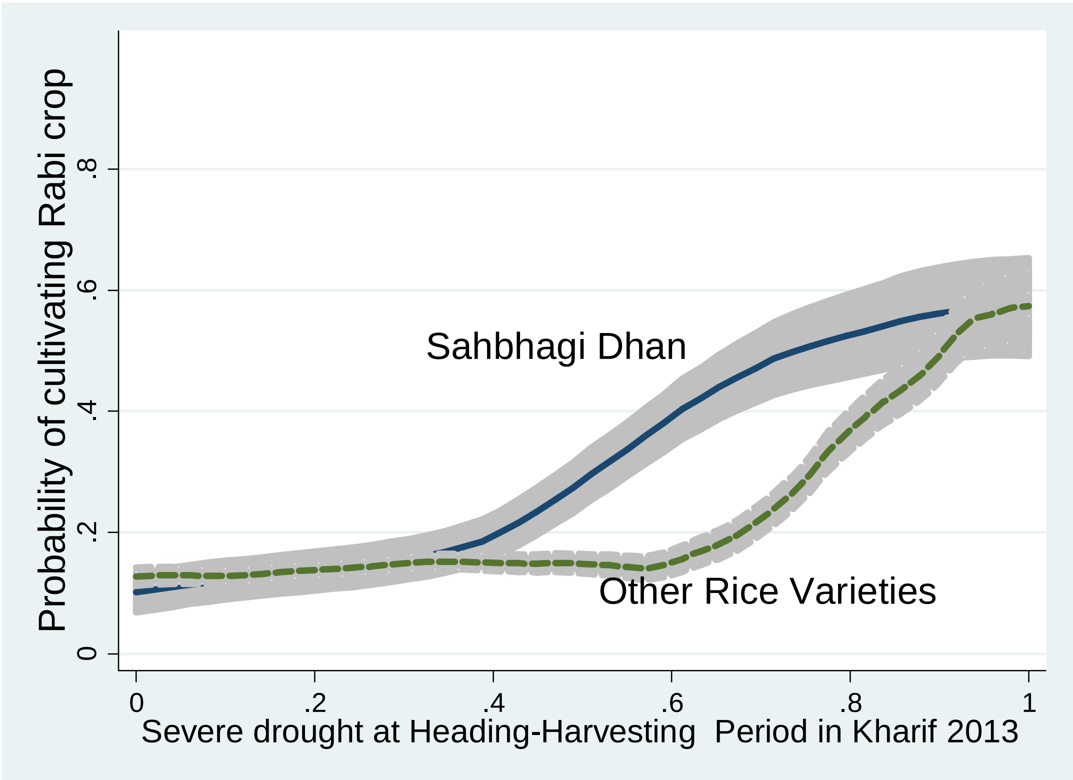

Figure 4. Probability of cultivating a Rabi crop and Severe Drought during Heading–Harvesting period in Kharif 2013 at the Plot Level: Among the 2013 Sample Farmers

Table 1. Sample Farmers in 2013 and 2014 surveys

State	Blocks	Villages	Households		
			2012	2013	2014*
	Number	Number	Number	Number	Number
Jharkhand	31	124	0	620	602
Odisha	28	154	210	770	759
West Bengal	7	58	210	290	284
Total	66	336	420	1,680	1,645

Notes: *Interviews with some households were delayed, and their data were not available at the time of writing this report.

Table 2. Balancing Test for the Random Selection of Treatment Households

Variables	Means		Probit with block dummies
	Control Households	Treatment Households	
	(1)	(2)	(3)
	mean	mean	Coef. (s.e)
Head age	48.2	48.5	0.0003
			(0.23)
Head education	5.3	5.1	0.0003
			(0.07)
Own land size (ha)	0.81	0.74	-0.046
			(1.27)
Scheduled Caste/Tribe	0.53	0.54	0.084
			(1.45)
Other backward caste (OBC)	0.31	0.33	0.095
			(1.56)
Own mobile phones	0.79	0.79	0.019
			(0.44)
Own Below Poverty Line card	0.63	0.65	0.015
			(0.85)
Own TV	0.83	0.77	-0.004
			(0.09)
Number of cattle	1.83	1.93	0.017
			(1.42)
Number of goats/sheep	1.36	1.43	0.002
			(0.25)
Number of chicken	2.12	1.89	-0.004
			(1.21)
Share of plots with irrigation	0.22	0.21	-0.027
			(0.52)
Share of low-land plots	0.18	0.16	-0.057
			(0.63)
Share of up-land plots	0.57	0.61	0.086
			(1.21)

Table 3. Area under Rice Varieties Grown in 2012 and 2013 Kharif: Treatment vs. Control

Rice Variety	Treatment Households			Control Households		
	2012	2013	Dif.	2012	2013	Dif.
	% of cultivation area		Dif. in %	% of cultivation area		Dif. in %
2012 Sample						
Sahbhagi Dhan	15.2	14.7	-0.5	0.1	0.1	0
Hybrid	0.1	0	-0.1	0	0.8	+0.8
Swarna	24.4	31.5	+7.1	36.3	32.8	-3.5
Lalat	13.2	10.9	-2.3	18.2	11.4	-6.8
IR64	0.1	0.3	0.2	0	0	0
Others	47.0	42.4	-4.6	45.4	55.0	+9.6
Total (%)	100	100		100	100	
	ha	ha	Dif. in ha	ha	Ha	Dif. in ha
Total area (ha)	210.5	198.4	-12.1	82.4	83.9	+1.5
2013 Sample						
Sahbhagi Dhan	0	32.9	+32.9	0.1	0.2	+0.1
Hybrid	14.6	8.0	-6.6	16.3	15.7	-0.6
Swarna	12.1	11.3	-0.8	11.7	13.4	+1.7
Lalat	9.4	6.3	-3.1	10.1	8.7	-1.4
IR64	8.9	2.9	-6.0	8.9	6.8	-2.1
Others	54.9	38.5	-16.4	52.9	55.1	+2.2
Total (%)	100	100		100	100	
	ha	ha	Dif. in ha	ha	Ha	Dif. in ha
Total area (ha)	373.0	362.7	-10.3	421.1	412.2	-8.9

Note:

Table 4. Rice Yields (tons/ha): Treatment vs. Control Households/Plots

	Treatment Households			Control Households		
	2012	2013	Dif.	2012	2013	Dif.
	Tons/ha (s.d)	Tons/ha (s.d)	Dif. [t-stat]	Tons/ha (s.d)	Tons/ha (s.d)	Dif. [t-stat]
All samples	2.60	2.31	-0.29**	2.34	2.22	-0.12
	(1.92)	(1.96)	[5.44]	(1.89)	(2.06)	[1.76]
2012 Samples						
Sahbhagi Dhan	2.78	2.28	-0.50**	n.a.	n.a.	
	(2.02)	(1.71)	[2.78]			
Other varieties	3.10	2.83	-0.32*	2.96	2.89	0.07
	(1.76)	(1.82)	[2.54]	(1.73)	(2.05)	[0.49]
Difference	-0.32*	-0.55**				
	[2.54]	[3.73]				
2013 Samples						
Sahbhagi Dhan	n.a.	1.46		n.a.	n.a.	
		(1.78)				
Other varieties	2.30	2.40	+0.10	2.18	2.04	-0.15*
	(1.93)	(2.05)	[1.25]	(1.90)	(2.03)	[1.99]
Difference		-0.94**				
		[9.34]				

Note: * 5 % significance, ** 1 % significance. (s.d)

Table 5. Growth Duration, Planting and Harvesting Month, and Second Crop Cultivation in 2013

Rice varieties	Growth duration in weeks	Planting month & week			Harvesting Month & week						Cultivated Second Crop after Kharif 2013
	Weeks	July			November					Dec	
		2nd	3rd	4th	1st	2nd	3rd	4th	5th	1st	
Sahbhagi Dhan	17.1										19.9
Lalat	17.7										2.5
Hybrid	20.4										16.2
IR64	20.7										13.4
Swarna	20.9										3.0
Others	20.6										12.0

Table 6. Percentage of Households who Cultivated Rabi Crops

	Treatment Households			Control Households		
	2012	2013	Dif.	2012	2013	Dif.
	% (s.d)	% (s.d)		% (s.d)	% (s.d)	
All plots	8.9	13.8	+4.9**	13.4	16.7	+3.3**
	(0.29)	(0.34)	[5.54]	(0.34)	(0.37)	[2.78]
2012 Samples						
SD Plots	3.4	3.2	-0.2	n.a.	n.a.	
	(18.3)	(17.6)	[0.14]			
Non-SD Plots	1.1	2.5	+1.4*	9.4	5.7	-3.7
	(10.5)	(15.7)	[2.10]	(0.29)	(0.23)	[1.87]
Difference	+2.3*	+0.7				
	[2.37]	[0.54]				
2013 Samples						
SD Plots	15.5	24.0	+8.5**	n.a.	n.a.	
	(36.2)	(42.8)	[3.83]			
Non-SD Plots	11.8	17.4	+5.6**	14.2	19.7	+5.5**
	(32.3)	(38.0)	[3.08]	(35.0)	(39.8)	[3.72]
	+3.7	+6.6**				
	[1.92]	[3.28]				

Table 7. Area under Rice Varieties Grown in 2012 and 2013 Kharif: Treatment vs. Control

Rice Variety	Treatment Households			Control Households		
	2012	2013	Dif.	2012	2013	Dif.
	% of cultivation area		Dif. in %	% of cultivation area		Dif. in %
2012 Sample						
All crops	1.2	2.9	+1.7	11.5	8.2	-3.3
Fallow	98.8	97.1	-1.7	88.5	91.8	+3.3
	ha	ha	Dif. in ha	ha	ha	Dif. in ha
Total cultivated area (ha)	2.4	5.7	+3.3	9.5	6.9	-2.6
2013 Sample						
Wheat	5.6	7.4	+1.8	7.9	7.6	-0.3
Mungbean	2.5	2.4	-0.1	2.2	2.2	0
Vegetables	0.5	2.1	+1.6	0.3	1.4	+1.1
Pulse	0.9	7.5	+6.6	1.5	7.7	+6.2
Other crops	4.5	3.1	-1.4	5.7	3.0	-2.7
Fallow	85.9	77.5	-8.4	82.3	78.1	-4.2
Total (%)	100	100		100	100	
	ha	ha	Dif. in ha	ha	ha	Dif. in ha
Total cultivated area (ha)	52.4	74.5	+22.1	81.6	90.4	+8.8

Note:

Table 8. Determinants of Rice Yield (RCT with Fixed Effects)

Variables	Basic model OLS (1)	Plot Level FE model (2)	(3)
	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)
Sahbhagi Dhan (=1)	-375.3***	-418.1***	-295.8**
	(-6.139)	(-5.628)	(-2.528)
Block level drought indicator			
Heading/flowering period	-1,343***	-1,260***	-1,205***
	(-14.04)	(-12.08)	(-10.75)
Heading/flowering period *x SD*			-370.1
			(-1.352)
Plot Characteristics			
Plot size in ha	-662.6***		
	(-12.49)		
Crop establishment: Broadcasting	-579.4***	-454.0***	-453.4***
Base groups is transplanting	(-10.25)	(-5.493)	(-5.486)
Irrigation: Underground water (=1)	272.8***		
	(3.678)		
Irrigation: Surface water (=1)	233.0***		
	(3.984)		
Low-land plot (=1)	273.8***		
	(4.816)		
Up-land plot (=1)	-253.0***		
	(-5.551)		
Household Characteristics			
Number of bulls	46.48**		
	(2.532)		
Household head: Age	-1.948		
	(-1.212)		
Household head: Education	6.270		
	(1.360)		
Number of adults	2.228		
	(0.209)		
Number of children	5.659		
	(0.433)		
Scheduled Caste/Tribe (=1)	-410.5***		
	(-6.812)		
Other Backward Class (=1)	15.86		
	(0.259)		
Year 2014 dummy	-310.1***	-265.6***	-263.4***
	(-7.684)	(-6.961)	(-6.898)
Constant	3,289***	3,025***	3,008***
	(24.95)	(68.26)	(65.18)

R-squared	0.176	0.061	0.061
Number of plots		4,487	4,487
Observations	8,540	8,724	8,724

Note: The standard errors of the OLS model are clustered at the household level.

Table 9. Determinants of Cultivating Rabi Crops among 2013 Sample

Variables	Probit Model[6]	Plot FE model	
	(1)	(2)	(3)
	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)
Sahbhagi Dhan (=1)	0.0308*	0.0325*	-0.0355
	(1.892)	(1.719)	(-1.294)
Block level drought dummies			
Heading/flowering period	0.152***		0.257***
	(7.291)		(11.09)
Interaction terms with SD			
Heading/flowering period *x SD*			0.146**
			(2.464)
Plot Characteristics			
Plot size in ha	0.0121		
	(1.505)		
Crop establishment: Broadcasting	0.0754***		
Base groups is transplanting	(5.136)		
Irrigation: Underground water (=1)	0.218***		
	(12.09)		
Irrigation: Surface water (=1)	0.206***		
	(12.03)		
Low-land plot (=1)	0.0140		
	(1.053)		
Up-land plot (=1)	-0.0350***		
	(-3.289)		
Household Characteristics			
Number of bulls	-0.0124***		
	(-3.044)		
Number of buffalos	-0.00543		
	(-0.695)		
Household head: Age	0.000612		
	(1.601)		
Household head: Education	0.00227**		
	(2.069)		
Number of adults	0.00196		
	(0.750)		
Number of children	0.000409		
	(0.132)		
Scheduled Caste/Tribe	-0.0125		
	(-0.842)		
Other Backward Class	0.0533***		
	(3.457)		
Year 2014 dummy	0.0589***	0.0610***	0.0652***

[6] The coefficients of the Probit model are marginal effects on the probability of cultivating second crops.

	(5.793)	(6.651)	(7.301)
Constant		0.140***	0.0608***
		(24.38)	(6.685)
R-squared		0.022	0.078
Number of plots			4,500
Observations	5,801	5,960	5,960

Table 10. Determinants of Cultivating Rabi Crops among 2012 Sample

	Probit Model	Plot FE model	
Variables	(1)	(2)	(3)
	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)
Sahbhagi Dhan (=1)	-0.00919	-0.00712	-0.00983
	(-1.113)	(-0.561)	(-0.417)
Block level drought dummies			
Heading/flowering period	-0.0246		0.00984
	(-0.851)		(0.357)
Interaction terms with SD			
Heading/flowering period *x SD*			0.00793
			(0.138)
Plot Characteristics			
Plot size in ha	0.0399**		
	(2.490)		
Crop establishment: Broadcasting	-0.0109		
Base groups is transplanting	(-0.841)		
Irrigation: Underground water (=1)	0.141***		
	(6.696)		
Irrigation: Surface water (=1)	0.0474***		
	(5.129)		
Low-land plot (=1)	-0.00801		
	(-1.041)		
Up-land plot (=1)	0.000282		
	(0.0420)		
Household Characteristics			
Household head: Age	-0.000194		
	(-0.802)		
Household head: Education	0.000691		
	(0.959)		
Number of adults	9.48e-05		
	(0.0663)		
Number of children	0.000497		
	(0.261)		
Scheduled Caste/Tribe	-0.00483		
	(-0.558)		
Other Backward Class	-0.00961		
	(-1.212)		
Year 2014 dummy	-0.00228	0.000664	0.00296
	(-0.263)	(0.105)	(0.356)
Constant		0.140***	0.0608***
		(24.38)	(6.685)
R-squared		0.010	0.081

Number of plots		1,413	1,413
Observations	2,839	2,876	2,876

Appendix

Appendix Table 1. Area-weighted Average Age of Rice Varieties in Eastern India

Variety Name	% of estimated area	Variety age: years since released	Varietal Turnover: average years since replaced the previous variety
	%	Years	years
Swarna	31.2	34	3
Pooja	3.7	14	5
Lalat	2.9	25	4
Moti	2.8	25	2
MTU 1001	2.8	18	4
Mahsuri	2.7	41	3
Swarna Sub1	2.6	4	2
Sambh Mahsori	2.3	27	4
Sarju-52	2.2	33	4
ARIZE 6444	2.1	6	4
Khandagiri	1.8	21	6
Kalachampa	1.5	14	9
Other Hybrid	2.8	11	2
Other Improved	11.2	19	5
Other Traditional	9.5	-	5
Unknown/ Don't Know	18.0	-	8
Total	100	25.6[A]	4.6 [A]

Source: Yamano et al. (2014).

Note: [A] Area weighted average.

Appendix Table A-2. Popular Rice Varieties cultivated in eastern India.

Rice variety	Year of release	Category	Designation	Number of farmers
Swarna	1979	MV	MTU 7029	1,789
Moti	1988	MV	CR 260-136-321	485
Pooja	1999	MV	CR 629-256	371
Sambh Mahsori	1986	MV	BPT 5204	347
ARIZE 6444	2007	Hybrid	Hybid 6444	330
Sarju-52	1980	MV	n.a.	317
Mahsuri	1972	Improved	n.a.	301
Lalat	1988	MV	ORS-26-2014-4	257
Swarna Sub1	2009	MV	n.a.	238
Vijetha	1995	MV	MTU 1001	160
Sonam	n.a.	Improved	n.a.	136
Khandagiri	1992	MV	OR 811-2	125
Kalachampa	1999	Traditional	n.a.	116
Sona	n.a.	Improved	n.a.	73
1010	n.a.	Improved	n.a.	54
Naveen	2005	Improved	CR-749-20-2	53
Niranjan	n.a.	Improved	n.a.	51
1018 (CR 1018)	n.a.	Improved	n.a.	50
Ranjit	1994	Improved	TTB 101-17	45
Moti Gold	n.a.	Improved	n.a.	44
Sarala	2001	Improved	CR-260-77-100	42
Komal	n.a.	Improved	n.a.	37
1009	n.a.	Improved	n.a.	33
PHB 71	1997	Hybrid	n.a.	32
Pratikshya	2005	Improved	OR S 201-5	32
Annapurna	1977	Improved	n.a.	30
Sita	1975	Improved	IR 931-67-2-2	29
IR64 Sub1	2013	Improved	n.a.	24
Rupali	n.a.	Improved	n.a.	20
Pant4	1983	Improved	IR 262/ Remadja	19
IR 36	1981	Improved	n.a.	19
Super Shyamili	n.a.	Improved	n.a.	17
Narendra 97	1992	Improved	NDR97	14
Pant11	1992	Improved	UPR 83-169	14
Kastori	1989	Improved		13
1017 (MTU 1017)	n.a.	Improved	n.a.	11
Gorakhnath	n.a.	Improved	n.a.	10
Other Hybrid	-	Hybrid	-	393

Other Improved	-	Improved	-	124
Other Traditional	-	Traditional	-	680
Unknown	-			1626
Total				**8561**

Source: Yamano et al. (2014).