Takashi Yamano
Manzoor H Dar
Architesh Panda
Ishika Gupta
Maria Luz Malabayabas
Eric Kelly

The impact of adopting risk-reducing, drought-tolerant rice in India

March 2018

Impact Evaluation Report 72

Agriculture

International Initiative for Impact Evaluation

About 3ie

The International Initiative for Impact Evaluation (3ie) is an international grant-making NGO promoting evidence-informed development policies and programmes. We are the global leader in funding, producing and synthesising high-quality evidence of what works, for whom, how, why and at what cost. We believe that using better and policy-relevant evidence helps to make development more effective and improve people's lives.

3ie impact evaluations

3ie-supported impact evaluations assess the difference a development intervention has made to social and economic outcomes. 3ie is committed to funding rigorous evaluations that include a theory-based design, use the most appropriate mix of methods to capture outcomes and are useful in complex development contexts.

About this report

3ie accepted the final version of the report, *Impact and adoption of risk-reducing drought-tolerant rice in India*, as partial fulfilment of requirements under grant OW4.1343 awarded under Open Window 4.

The 3ie technical quality assurance team for this report comprises Diana Lopez-Avila, Markus Olapade, Emmanuel Jimenez, Stuti Tripathi, an anonymous external impact evaluation design expert reviewer and an anonymous external sector expert reviewer. The 3ie editorial production team for this report comprises Beryl Leach, Angel Kharya and Akarsh Gupta.

The report content has been copy-edited and formatted for publication by 3ie. However, despite best efforts in working with the authors, some figures and tables could not be improved. We have copy-edited the content to the extent possible. All the content is the sole responsibility of the authors and does not represent the opinions of 3ie, its donors or its board of commissioners. Any errors and omissions are also the sole responsibility of the authors. All affiliations of the authors listed in the title page are those that were in effect at the time the report was accepted. Any comments or queries should be directed to the corresponding author, Takashi Yamano, at t.yamano@irri.org.

Funding for this impact evaluation was provided by 3ie's donors, which include UK Aid, the Bill & Melinda Gates Foundation and the Hewlett Foundation. A complete listing of all of 3ie's donors is available on the 3ie website.

Suggested citation: Yamano, T, Dar, MH, Panda, A, Gupta, I, Malabayabas, ML and Kelly, E, 2018. *Impact and adoption of risk-reducing drought-tolerant rice in India*, 3ie Impact Evaluation Report 72. New Delhi: International Initiative for Impact Evaluation (3ie).

Cover photo: ICCo India

Impact and adoption of risk-reducing drought-tolerant rice in India

Takashi Yamano
International Rice Research Institute (IRRI)

Manzoor H Dar
IRRI

Architesh Panda
IRRI

Ishika Gupta
IRRI

Maria Luz Malabayabas
IRRI

Eric Kelly
University of California at Berkeley

3ie Impact Evaluation Report 72

March 2018

International Initiative for Impact Evaluation

Acknowledgments

We received financial support from the International Initiative for Impact Evaluation (3ie). We are grateful for the generous support from 3ie.

Summary

Extremely high temperatures during vegetative growth of rice reduces tiller number and plant height. Some experts argue that, in some parts of Asia, current temperatures are already approaching critical levels during the susceptible stages of plant growth. To reduce yield loss caused by drought, drought-tolerant crops have been developed. Sahbhagi Dhan is a rice variety that is tolerant against drought, partly because it matures early and therefore avoids the high temperatures that affect long-duration rice varieties. In addition, short growth duration can allow farmers to cultivate another crop immediately after the rice harvest. A diversified income source makes farmers resilient against negative income shocks.

We used a randomized controlled trial to evaluate Sahbhagi Dhan by providing Sahbhagi Dhan seeds to randomly selected farmers in treatment villages in either 2012 or 2013. The treatment farmers were subsequently interviewed by enumerators along with the same number of randomly selected control households in nearby villages. The 2012 randomized controlled trial involved 420 farmers; the study area was significantly expanded in 2013 to cover different drought conditions, and 1,270 farmers were added to the sample.

The results clearly show that the drought measured by the index significantly reduces rice yield. The magnitude of the estimated coefficient suggests that yield declines by 1.3 tons per hectare if farmers experience severe drought. Regarding the yield of Sahbhagi Dhan, we find that its yield is lower than that of other varieties by 0.3 to 0.4 tons per hectare. Contrary to earlier agronomic studies on Sahbhagi Dhan, we find little evidence that Sahbhagi Dhan is more tolerant of drought than other rice varieties. The drought conditions in the fields in 2012 and 2013 might have been unfavorable for Sahbhagi Dhan. Continuous monitoring and evaluation of Sahbhagi Dhan in farmers' fields should be conducted.

We found evidence that the short duration of Sahbhagi Dhan helps farmers to cultivate crops after *kharif* (the main agricultural season). The results in this report indicate that the probability of producing second crops after *kharif* is higher by 3 percentage points in Sahbhagi Dhan plots than in 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 in Sahbhagi Dhan plots. After drought, farmers may feel a need to compensate for crop loss due to drought by cultivating more crops after the season.

The findings in this project suggest targeting strategies for Sahbhagi Dhan. The main benefit of Sahbhagi Dhan appears to be its 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 to drought and other shocks during *kharif* by diversifying income sources. Experiments in farmers' fields are different from agronomic experiments on research stations. Although we do not observe its drought tolerance in this report, it can become tolerant under certain drought conditions. The drought tolerance of Sahbhagi Dhan continues to be monitored among farmers.

Contents

List of figures and tables

Appendix figures and tables

Abbreviations and acronyms

BGREI	Bringing Green Revolution to Eastern India
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
NFSM	National Food Security Mission
RCT	randomized controlled trial
STRASA	Stress-Tolerant Rice for Africa and South Asia

1. Introduction

The largest number of food-insecure people live in South Asia, where about 300 million people are undernourished (FAO 2012). Concern exists 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 temperatures will lead to lower rice yield as a result of shorter growing periods (IPCC 2014). Wassmann and others (2010) conclude that, in some parts of Asia, current temperatures are already approaching critical levels during the susceptible stages of plant growth. Effective adaptation of cropping technologies and practices that mitigate the negative impact of climate change are imperative to enhancing food security and sustainable livelihoods in developing countries such as India.

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

Randomized controlled trials (RCTs) have been used to assess the economic impacts of new agricultural technologies. A recent study by Dar and others (2013) used an RCT to evaluate the impact of cultivating a submergence-tolerant rice variety in eastern India. In this study, we use an RCT to evaluate the performance of Sahbhagi Dhan by providing Sahbhagi Dhan seeds to randomly selected farmers in treatment villages in either 2012 or 2013. The treatment farmers were subsequently interviewed by our enumerators, along with the same number of randomly selected control households in nearby villages. The 2012 RCT involved 420 farmers. In 2013, the study area was significantly expanded to cover different drought conditions, and 1,270 farmers were added to the sample.

In this report, we estimate the impact of cultivating Sahbhagi Dhan on rice yield and the probability of cultivating another crop after harvesting Sahbhagi Dhan.

2. Intervention, theory of change and research hypotheses

2.1 Intervention

The study looked at the impact of Sahbhagi Dhan rice in the eastern Indian states of West Bengal and Odisha, where rice is a major staple food and the risk of drought is high. It builds on an RCT experiment already initiated in collaboration with the International Rice Research Institute (IRRI). Focusing on two geographically separated states increased the likelihood of observing drought events during the project period.

The impact question of first-order importance was to measure the effective yield of this new seed. Although test plots have demonstrated the advantage that Sahbhagi Dhan provides in drought conditions, we wanted to establish whether this holds true under the circumstances of smallholder farming, particularly in its behavior in response to constraints and context specificities. We proposed to measure both the average treatment effect on the randomly selected group of farmers who received minikits and the treatment effect on a group of farmers that would have endogenously chosen to adopt Sahbhagi Dhan seeds (Treatment on the Treated) once made available through seed multiplication by minikit recipients. This was done as follows.

IRRI had started to diffuse the seed in 2010 and 2011 to about 300 farmers in selected areas. In early 2012, IRRI agreed to extend its pilot diffusion in Odisha and West Bengal following an experimental design that would permit the impact analysis that we are describing in this report. The standard process by which the government of India and IRRI promote new seeds is through the distribution of minikits to a small number of farmers in each village. We thus built on this practice and adapted it to an RCT design.

In preparation for the RCT, a list of all drought-prone villages was constructed and stratified into four weather risk categories. Some 512 villages were randomly selected in equal numbers from the four risk categories to become the study sample. The 128 villages in treatment group 1 (32 randomly selected from each of the four risk categories) each received five minikits of Sahbhagi Dhan rice seeds in May/June 2012. The 128 villages of treatment group 2 received the same treatment in May/June 2013, and treatment group 3 followed in May/June 2014. The 128 control villages received no treatment.

The selection of farmers within each treatment village was done as follows. First, a survey was carried out to collect village-level information. As part of this survey, a list of 25 eligible farmers was obtained in each village, defined as rice farmers who would benefit from Sahbhagi Dhan rice because of having at least one plot in upland drought-prone areas and 5 acres or less in total land. Five farmers were randomly chosen from this list to receive a free 5-kilogram minikit of Sahbhagi Dhan seeds, accompanied by a brochure with instructions for cultivation. Five other farmers were randomly selected to be part of the study, but did not receive minikits. In order to ensure compliance with the randomization, the enumerators had to make a phone call to obtain the five random numbers indicating to whom to give the minikits.

2.2 Theory of change for policy influence and research hypotheses

We describe how we communicate with policymakers and achieve final outcomes through the steps in Figure 1.

- Step 1: In our study, we address the following policy questions: How does a newly developed, drought-tolerant rice variety, Sahbhagi Dhan, benefit rice farmers practicing rainfed agriculture in eastern India? How much does Sahbhagi Dhan mitigate yield losses due to drought? Is there any trade-off from switching to Sahbhagi Dhan from other rice varieties?
- Step 2: Our immediate and primary policy target is the National Food Security Mission (NFSM), which promotes agricultural technologies for farmers in eastern India, under a mega-scheme called Bringing Green Revolution to Eastern India (BGREI). NFSM/BGREI conducts large-scale block demonstrations on about 270,000 hectares across eastern Indian states and has already promoted a submergence-tolerant rice variety, Swarna-Sub1, which was developed and disseminated by the IRRI.
- Step 3: We hope that the results from our RCTs will provide evidence of the benefits of Sahbhagi Dhan and provide scientific legitimacy to the adoption of Sahbhagi Dhan in NFSM block demonstrations. A large-scale demonstration of Sahbhagi Dhan is expected to disseminate this rice variety quickly in drought-prone areas of eastern India.
- Step 4: Because Sahbhagi Dhan is a drought-tolerant rice variety, its benefits are realized only under drought conditions. Thus, if drought occurs during our three-year study period, the demand for our research results increases dramatically. Indeed, eastern India experienced a modest drought at the beginning of the 2012 *kharif* (the main agricultural season), which was the first year of our randomized controlled trial of Sahbhagi Dhan.
- Step 5: We maintain close contact with the director of NFSM, Mukesh Khullar, who was identified as one of the key influencers. The results from our RCT can reach Mr Khullar and other key members of the Ministry of Agriculture.
- Step 6: We assume that the Indian government will maintain its keen interest in increasing agricultural productivity in rainfed rice production in eastern India because this is the area where poverty is concentrated and frequent natural disasters, such as large-scale droughts and floods, devastate smallholders. We also assume that policymakers in India and other countries will have an interest in our study because climate change is expected to increase the frequency of natural disasters.

The potential benefits of drought-tolerant rice go beyond South Asia. Some 90 per cent of rice production in African countries is unirrigated. The Stress-Tolerant Rice for Africa and South Asia (STRASA) project is a joint effort between IRRI and the Africa Rice Center, supported by a US$20 million grant from the Bill & Melinda Gates Foundation. The project targets 22 countries, 19 of which are in Africa. Drought-tolerant rice varieties are expected to spread rapidly throughout Africa over the next 10 years. The existing collaborative arrangement between IRRI and the Africa Rice Center under STRASA is the channel through which the findings will be disseminated and applied.

IRRI has already demonstrated capacity to reach large numbers of smallholders, as more than 100 million hectares of rice planted each year contain germplasm from its varietal improvement efforts. The research will be carried out under STRASA, which has a goal of providing stress-tolerant varieties and improved management to 20 million farmers in South Asia and across Africa by 2018. The project is conducted in Nigeria, Benin, Senegal, Burkina Faso, Ghana, Guinea, the Gambia, Mali, Côte d'Ivoire, Guinea and Sierra Leone in West Africa; Mozambique, Tanzania, Uganda, Ethiopia, Madagascar, Rwanda, Burundi and Kenya in eastern and southern Africa; and India, Bangladesh and Nepal in South Asia.

2.3 Theory of change of the intervention

We expected the intervention to have a strong impact on the adoption of Sahbhagi Dhan. The intervention theory of change is described in Figure 2.

Activity 1: Under our RCT, treatment farmers receive 5-kilogram bags of Sahbhagi Dhan.

Assumptions: For our RCT to have measurable impacts among farmers, two assumptions have to be held. First, no major events should occur that disrupt rice production, other than drought. Otherwise, it would be difficult to identify the impact of the use of Sahbhagi Dhan in the RCT. Second, across treatment and control villages, various levels of drought should occur for us to identify the (stress-mitigating) impacts of the use of Sahbhagi Dhan. If the drought conditions were uniform across sample villages, it would be difficult to identify the impacts. To ensure a sufficient variation in drought conditions, we expanded survey areas in 2014.

Outcome 1: By producing Sahbhagi Dhan, the treatment farmers mitigate the production loss due to drought and realize a higher rice yield under drought, compared with control farmers in nearby control villages.

Outcome 2: In the following rice season, the treatment farmers expand their areas under Sahbhagi Dhan by using Sahbhagi Dhan seeds from their own production.

Outcome 3: Treatment farmers exchange Sahbhagi Dhan seeds with neighboring farmers, including control farmers.

Final Outcome: The total area under Sahbhagi Dhan significantly expands and rice production loss in target areas is significantly reduced.

Figure 1: Theory of change of policy influence

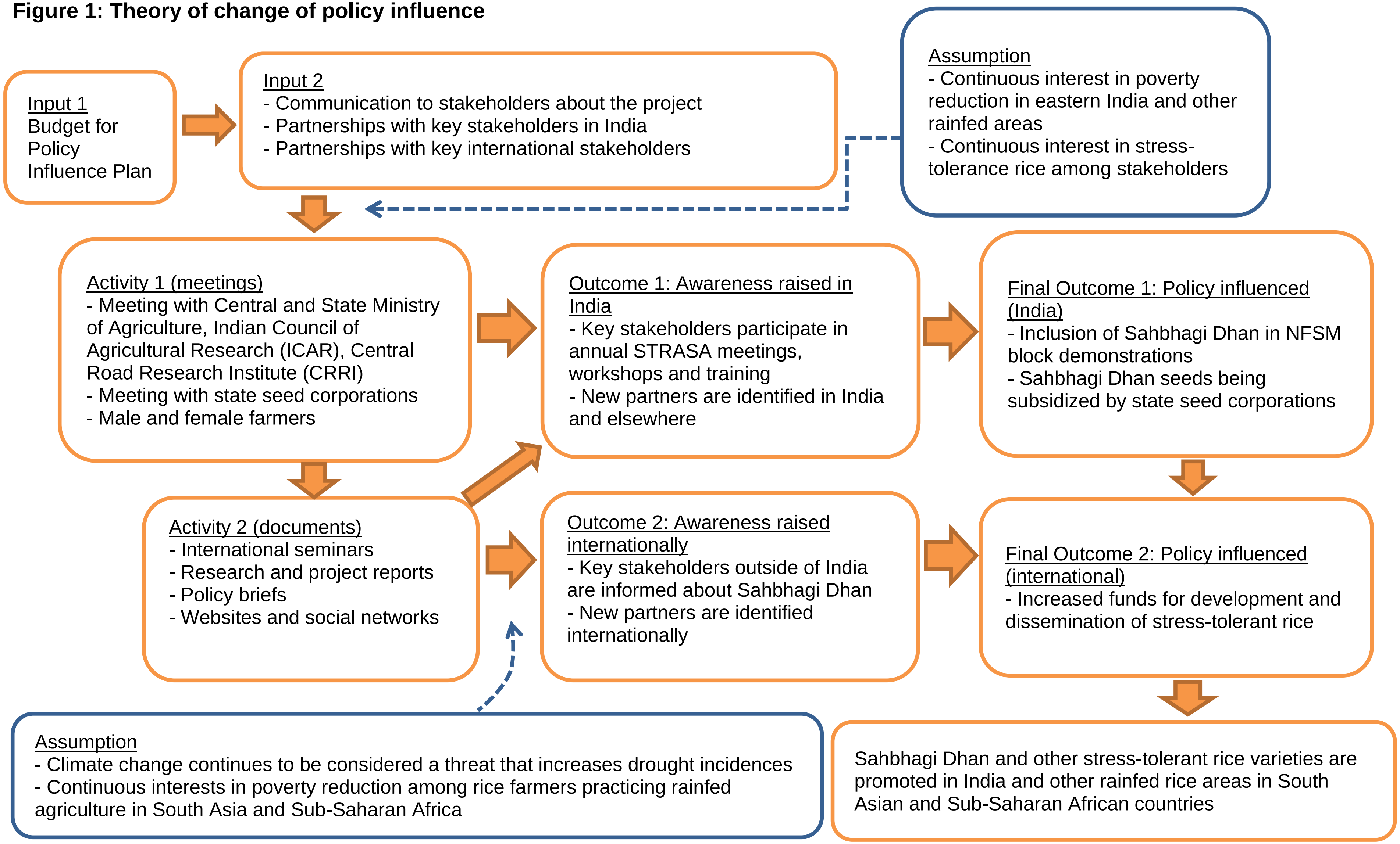
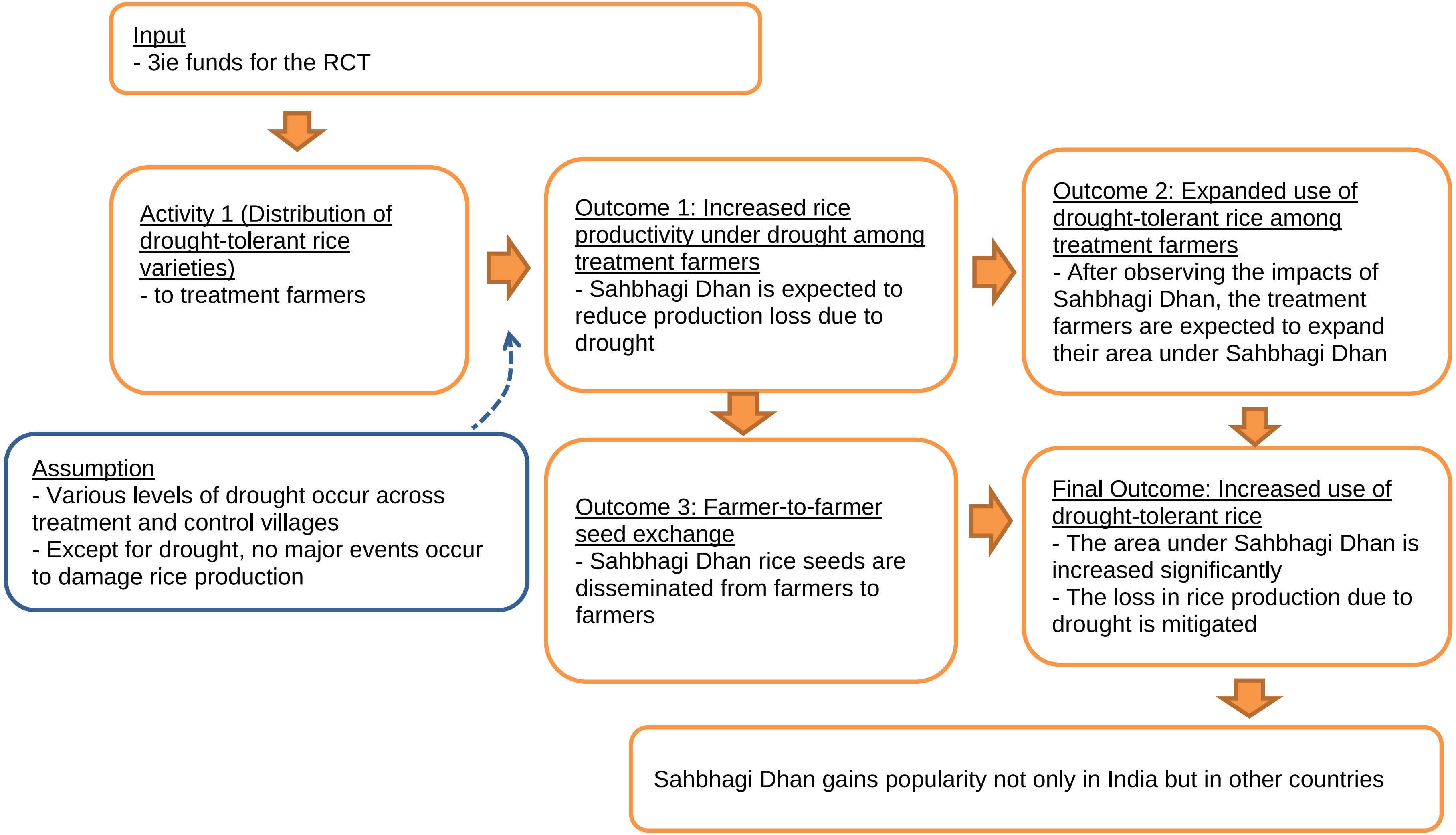


Figure 2: Theory of change of intervention



3. Context

3.1 Climate change

Under a plausible scenario, climate change is likely to have an impact on food production in India and around the world. Climate change is expected to affect yield (Tubiello et al. 2007; Lobell et al. 2011). Recent findings from the Intergovernmental Panel on Climate Change (IPCC) show that, with or without adaptation, negative impacts on average yields will occur from the 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 temperatures will lead to lower rice yields as a result of the shorter growing period (IPCC 2014). With the rise in temperature, the rice development process accelerates and reduces the duration of growth. Thus, rural poverty in parts of Asia could be exacerbated because of the impact of temperature rises on the rice crop and the increase in food prices and the cost of living (Hertel et al. 2010). Effective adaptation of cropping technologies and practices that mitigate the negative impacts of climate change will be critical in enhancing food security and sustainable livelihoods, especially in developing countries such as India.

Livelihoods 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 to crop varieties that are resistant to climate stress is among the most cited adaptation measures (Westengen et al. 2014).

3.2 Current use of rice varieties in eastern India

Since the Asian Green Revolution, modern rice varieties have helped farmers increase rice yield (David and Otsuka 1994; Estudillo and Otsuka 2013) and reduce poverty (Otsuka et al. 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 continue to 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 and others (2014) estimated the area under rice varieties in the region. The most popular rice variety, Swarna, is estimated to occupy 4.6 million hectares, or 31 per cent of the total rice area in the study area (Yamano et al. 2014). Because the second most popular variety is estimated to cover only 3.7 per cent of the total rice area, the popularity of Swarna is unmistakable. All but two of the top ten varieties were released before 2000; Swarna was released in 1979. The area-weighted age of rice varieties is about 25 years – very high, compared with that in other developing countries, such as the Philippines (Launio et al. 2008).

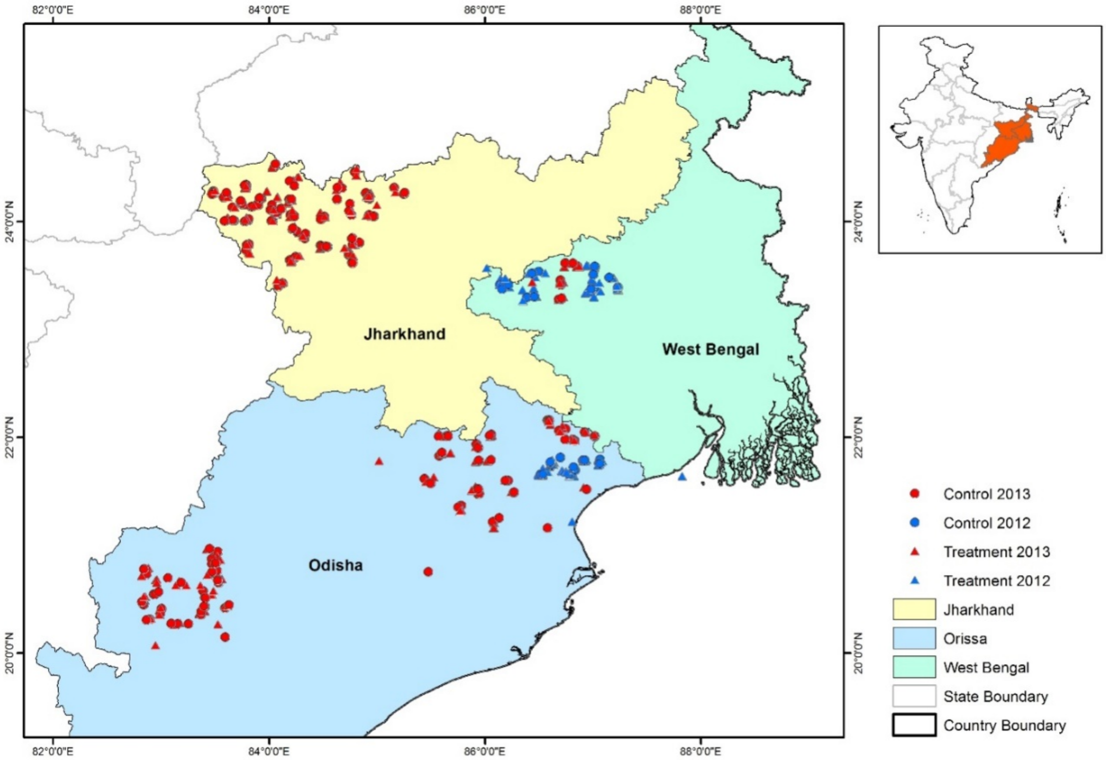
Yamano and others (2014) also found a submergence-tolerant rice variety, Swarna-Sub1, which was released in India in 2009. The total area under Swarna-Sub1 is about

376,500 hectares, which accounts for 2.6 per cent of the total rice area and places Swarna-Sub1 as the seventh most popular rice variety in terms of area coverage. Based on the number of users, Swarna-Sub1 is the fifth most popular rice variety; an estimated 704,000 farmers cultivated it in 2013. Only a small number of farmers were found cultivating Sahbhagi Dhan in *kharif* 2013.

3.3 Study sites

For this project, in 2011 we selected two areas – one near the border of West Bengal and Jharkhand and the other near the border of West Bengal and Odisha (Figure 3). In 2012, we added three areas: the far west side of Jharkhand, the western side of Odisha and the near-west side of the 2011 site near the border of West Bengal and Odisha. All these areas are drought-prone and poor. We expanded the study areas to capture variation in drought conditions.

Figure 3: Map of treatment and control



Note: Blue markers indicate locations of 2012 sample villages. Farmers in the 2012 treatment villages received 5-kilogram Sahbhagi Dhan minikits before the 2012 *kharif* season started. Farmers in the 2013 treatment villages received the minikits before the 2013 *kharif* season started.

In Table 1, we present daily rainfall data from 83 weather stations in our study area. We used the data to construct several rainfall measures in line with the existing literature. The top panel of the table shows that average monthly rainfall was lowest in 2010, a year that is known as a drought year in our study area. To understand the rainfall deviation from its mean, z-scores are constructed in the second panel. They confirm that 2010 was a drought year. A common definition of drought is shown in the third panel, as a year during which average monthly rainfall is at least one standard deviation below its mean.

According to this definition, drought occurred at 51 per cent of the weather stations in 2010 and at 11 per cent in 2013. The maximum number of consecutive days, which is important for plant growth but less directly related to average monthly rainfall, is shown in the bottom panel. Various other rainfall measures have been constructed, but the next section will show that the variables defined in the table are the most predictive of rice yield.

Table 1: Seasonal rainfall patterns, 2009–2013

Seasonal rainfall variables of the 83 stations	Year	N	Mean	Std. dev.
Average monthly rainfall in mm	2009	68	233.2	83.3
Daily rainfall data are averaged across the main rice-growing season from June until September. This variable shows the average monthly rainfall across this period in millimeters. If more than 20 daily rainfall observations are missing, this variable is set to missing.	2010	73	177.2	62.4
	2011	71	294.1	86.4
	2012	79	242.3	63.1
	2013	54	236.9	73.5
Average monthly rainfall z-score	2009	68	−0.05	0.77
For each station separately, the mean and standard deviation of average monthly rainfall (the variable above) are calculated from 2009 until 2013. The z-score equals the average monthly rainfall minus the mean of the weather station, divided by its standard deviation.	2010	74	−0.86	0.55
	2011	73	0.78	0.73
	2012	77	0.19	0.65
	2013	54	−0.08	0.76
Drought	2009	68	5.9	23.7
A year is defined as a drought year if the average monthly rainfall is at least one standard deviation below the weather station mean. In the summary statistics, this number is multiplied by 100 to show the percentage of stations that experienced drought in each year.	2010	74	51.4	50.3
	2011	73	2.7	16.4
	2012	77	1.3	11.4
	2013	54	11.1	31.7
Maximum number of days without rain	2009	67	15.7	4.9
This is the largest number of consecutive days between June and September during which no daily rainfall was recorded. If more than four daily rainfall observations are missing, this variable is set to missing.	2010	71	10.8	3.1
	2011	70	9.2	3.4
	2012	78	10.1	2.9
	2013	47	14.3	6.6

Note that all variables are defined over the rice-growing season, from June to September. Although other definitions have been used, these months most strongly coincide with the rice-growing season in the area as well as the main rainfall season. Given the importance of drought for our study, Table 2 gives the absolute frequencies of drought from 2009 to 2013, as defined above. A subset of farmers first planted Sahbhagi Dhan in 2012, during which only one block experienced drought. Drought was more common in 2013, the second year of our study, but the number of observations was smaller because of the delay in weather data collection.

Table 2: Drought occurrence

Year	N	Drought frequency	Non-drought frequency
2009	68	4	64
2010	74	38	36
2011	73	2	71
2012	77	1	76
2013	54	6	48

To explore drought in a larger geographic area, Table 3 repeats the summary statistics of average monthly rainfall shown in Table 1, but no longer sets observations to missing if too many daily observations are missing. This means the estimates become noisier, because average monthly rainfall is calculated by averaging across all daily observations. This measure, shown in the second panel of Table 3, is referred to as 'average monthly rainfall extrapolated'. To demonstrate the difference between the usual and extrapolated version of average monthly rainfall, the bottom panel shows the number of days that are missing during the June to September period. As expected, this is highest for 2013. The extrapolated rainfall measure shows lower average rainfall in 2013.

Table 3: Seasonal rainfall patterns, 2009–2013 extrapolated

Seasonal weather measured	Year	N	Mean	Std. dev.
Average monthly rainfall in mm	2009	68	233.2	83.3
	2010	73	177.2	62.4
	2011	71	294.1	86.4
	2012	79	242.3	63.1
	2013	54	236.9	73.5
Average monthly rainfall *extrapolated*	2009	79	225.5	82.5
This variable is similar to average monthly rainfall in mm, with the only difference that observations are not set to missing if any daily rainfall observations are missing.	2010	79	173.4	62.4
	2011	82	292.7	86.5
	2012	83	242.0	63.6
	2013	81	206.5	82.7
Number of missing days	2009	83	13.6	31.8
The number of daily rainfall observations that are missing in the data.	2010	83	8.3	27.0
	2011	83	6.5	18.6
	2012	83	1.9	6.8
	2013	83	20.9	31.5

Table 4 shows drought occurrence based on the extrapolated rainfall measure and confirms that a larger number of stations experienced drought in 2013. Although these numbers should be interpreted with caution, they indicate that, unlike in 2012, drought occurred in a few geographic areas in 2013.

Table 4: Drought occurrence extrapolated

Year	N	Drought frequency	Non-drought frequency
2009	79	4	75
2010	79	35	44
2011	82	2	80
2012	83	1	82
2013	81	16	65

Several subjective weather measures were collected in the farmer and village surveys, but these should be interpreted with caution because of recall error and because it is often challenging for farmers to distinguish between drought and its effect on their crops.

In the village survey, the village head was asked, ‘When was the worst drought in the last five years?’ Results are shown in Table 5. The responses are not fully consistent with the annual weather data shown in Table 3, but they have in common that 2012 was not considered a drought year.

Table 5: Farmers’ responses on drought severity in last four years

Year	Number of observations	Number of observations (%)
2012	13	6.2
2011	60	28.6
2010	58	27.6
2009	79	37.6

Note: This table shows the village head’s answer to the question, ‘When was the worst drought in the last four years?’

In the household survey in 2014, respondents were asked about their perception of drought in *kharif* 2013. They ranked severity of the drought on a scale of zero to four – no drought, mild drought, severe drought and very severe drought – for five rice growth periods (sowing, tillering, panicle initiation, flowering and harvesting). According to respondents’ perception of drought, drought occurred less frequently in the sowing period: more than 66 per cent of respondents indicated that they did not experience drought in this period. On the other hand, drought occurred more frequently in the harvesting period as indicated by 29 per cent of the respondents.

Regarding the degree of severity, the drought was severe during panicle initiation and flowering: more than 10 per cent of the respondents indicated that they experienced very severe drought during these periods. Rice is vulnerable to drought during these periods; this could be why respondents felt that the drought was very severe during these periods.

Table 6: Subjective drought perceptions over five growing periods in the 2013 *kharif* season

	Period 1	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Drought level	Sowing	Tillering	Panicle initiation	Flowering	Harvesting
No drought (%)	66.6	53.8	49.2	45.4	29.3
Mild (%)	22.9	24.5	21.1	23.7	38.9
Severe (%)	7.8	15.2	18.3	20.2	25.2
Very severe (%)	2.7	6.5	11.4	10.7	6.7

Note: The number of observations is 1,575.

The information presented above shows that the study sites are representative of drought-prone conditions of eastern India, and the results from our study indicate the following:

- The randomized control sites for this project are large enough to pass external validity; we should be able to draw policy implications that are relevant to farmers who live outside of the study sites.

- The study sites should be considered as representative of drought-prone areas of eastern India where agriculture is mostly rainfed.
- They are also representative in terms of the socioeconomic conditions of rice farmers in the region because they were selected randomly and consisted of a large number of farmers. Respondents include male and female farmers from all caste and economic classes.

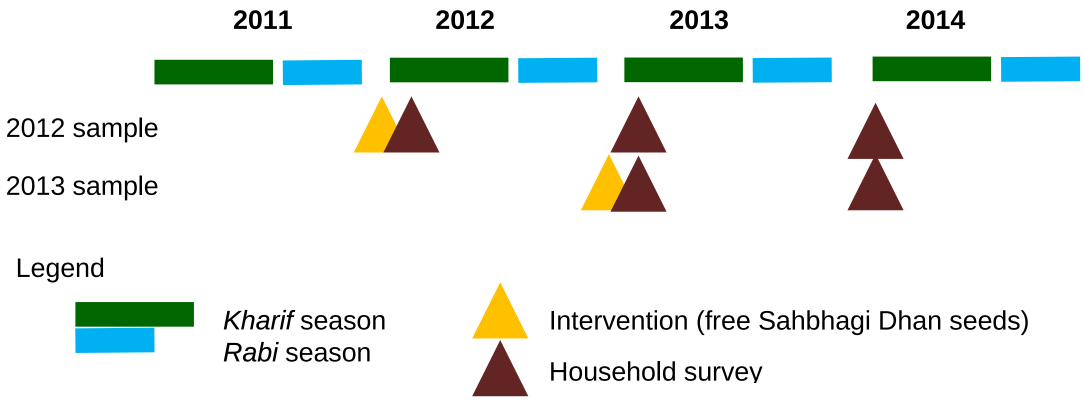
4. Timeline

In 2012, this randomization procedure was carefully implemented in the 128 villages of the first treatment group and, since the minikits were free of charge, compliance with the treatment was above 99 per cent. Selection of 10 additional farmers to be included in each of the 128 treatment villages in successive rounds of the experiment was made as part of the first intensive survey that took place in March 2013.

Surveys were carried out in March of 2013, 2014 and 2015, after the harvest and threshing had been completed and rice yields were known (Figure 4). Data were collected on farming practices (crop and variety choices, yield, agrochemical inputs and labor activities), household characteristics (income, education, household composition and caste), attitude toward uncertainty (risk aversion, ambiguity aversion, loss aversion and drought risk perceptions) and diffusion of seeds (gifts, selling and buying). Most of the basic information was collected in the first survey, allowing follow-up surveys to be shorter. The first survey collected two-year recall information on farming practices. All surveys included all households that served as treatments or controls in each wave of the three-year rollout. This data collection thus resulted in a three- to five-year panel of 5,120 farmers, with the number of years depending on whether the variable was part of the recall or not. Detailed household characteristics were collected, allowing us to study heterogeneous effects along the dimensions of assets, gender and caste.

Variation in drought occurrence in space and time and gradual rollout of the Sahbhagi Dhan minikits allowed us to estimate the yield impact of using Sahbhagi Dhan seeds under different rainfall and temperature circumstances for the first generation of randomly selected users. Observation of these same households in subsequent years helped us understand how learning affects yield outcomes. Observation of endogenous adopters among the original control households similarly allowed measuring both Sahbhagi Dhan effects and how this varies with years of experience. These endogenous adopters also revealed characteristics of adopters in the different years of the diffusion process and the channels through which diffusion occurs.

Figure 4: Timeline of interventions and surveys



5. Evaluation: design, methods and implementation

5.1 Randomized controlled trial: study design and balancing test

In May and June 2012, we conducted an RCT by selecting 128 treatments and 128 control villages in one district in Odisha and two districts in West Bengal. In each treatment village, 5 farmers were randomly chosen to receive a minikit with 5 kilograms of Sahbhagi Dhan seeds, accompanied by a brochure with instructions for cultivation. To ensure compliance with the randomization in selecting treatment farmers, the enumerators created a list of 100 households, with village officers, in the village and telephoned an officer in New Delhi to obtain 5 random numbers. In the control villages, five farmers were selected according to the same protocol. The 2012 sample thus consisted of 256 villages and 5 farmers per village, who were all interviewed in multiple surveys.

In 2013, we expanded the study area by: (1) taking 79 sample villages out of the 256 sample villages in the 2012 RCT; and (2) adding 252 villages across 6 more districts in Odisha and Jharkhand. 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 nearby 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; and
3. In each block, identified a rainfall station and randomly selected nearby villages.[1]

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 select five households. Of the 4 villages, 2 were selected as treatment villages and the other 2 were selected as control villages.

After the household selection, we conducted a household survey from 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

[1] Daily rainfall data were collected from the rainfall stations to identify drought conditions. However, for the analysis for this report, rainfall information was unavailable.

household survey did treatment households receive Sahbhagi Dhan minikits. In the five-month period of April to August 2014, we conducted a follow-up survey of the same sample households. Table 7 describes the distribution of sample households across the three states.

Table 7: Sample farmers in 2013 and 2014 sample

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

Note: *Interviews with some households were delayed in 2014 and their data were not available at the time of writing this report.

Of the 336 total villages, 79 were from the 2012 sample, with an additional 257 chosen in 2013. The survey sample included 420 farmers in 2012 and 1,260 farmers in 2013, for a total of 1,680. Half of the sample villages and half of the sample households were in the treatment group. In Figure 3, the 2012 sample villages are marked by blue, while the 2013 sample villages are marked by red. The treatment village markers are triangles, while the markers of the control villages are circles. Out of 1,680 households, 1,645 were re-interviewed in 2014. In Figure 3, it is clear that there are four clusters of sample villages. These clusters are in drought-prone areas and distanced from each other. Thus, it is expected that the sample villages would be exposed to different drought conditions in a given year, providing opportunities to identify the impacts of adopting Sahbhagi Dhan under different levels of drought.

5.2 Balancing test

To investigate whether the treatment and control households were randomly selected, we compared the basic household characteristics of the two groups (Table 8). 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 in both groups; the t-test confirms that the difference (1.3 years) is not statistically significant. We also found no difference in household size and farm size (in hectares). 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.

Table 8: Balancing test for the random selection of treatment households

Variables	Means		Probit with block dummies
	Control households (1)	Treatment households (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	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 chickens	2.12	1.89	−0.004 (1.21)
Share of plots with irrigation	0.22	0.21	−0.027 (0.52)
Share of lowland plots	0.18	0.16	−0.057 (0.63)
Share of upland plots	0.57	0.61	0.086 (1.21)

6. Program or policy: design, methods and implementation

We set our primary policy objective to be to inform policymakers from the Ministry of Agriculture about the benefits of Sahbhagi Dhan among rice farmers practicing rainfed agriculture in drought-prone areas of eastern India. The aim was that the ministry, with the help of its mega-schemes such as NFSM and BGREI, would include Sahbhagi Dhan for promotion in eastern Indian states.

Our objective will be partly fulfilled when NFSM includes Sahbhagi Dhan in its block demonstrations and the seed corporations carry out large-scale production of the seeds. This is a realistic objective, because NFSM already includes a submergence-tolerant rice variety, Swarna-Sub1, in its demonstrations in submergence-prone areas. NFSM staff members are keen to learn about Sahbhagi Dhan, because their mandate also includes assisting rice farmers practicing rainfed agriculture in drought-prone areas, where this variety has wide scope.

Our assessment of Sahbhagi Dhan from an RCT will provide rigorous scientific evidence for policymakers and provide guidance for inclusion of Sahbhagi Dhan in their promotional programs. If the results from our study show significant benefits of adopting Sahbhagi Dhan among rice farmers practicing rainfed agriculture in drought-prone areas, the ministry will make larger efforts to scale up use of the variety through extensive promotional activities, such as cluster demonstrations, that will create awareness of and demand for the seed. The ministry can also urge the state seed corporations to take up large-scale seed production of Sahbhagi Dhan so that certified seed is available to farmers in a short period.

The broader objective of the present study includes informing policymakers in other South Asian countries, such as Bangladesh, and in Sub-Saharan African countries about the benefits of drought-tolerant rice varieties. Through the STRASA project, IRRI has a large and effective research and policy network throughout South Asia and Sub-Saharan Africa. We plan to disseminate the results from the present evaluation through the STRASA network to encourage policymakers to invest in development and dissemination of stress-tolerant rice varieties in their countries. We also believe that this RCT study will set a standard for future evaluation studies in the target areas.

7. Impact analysis and results of the key evaluation questions

7.1 Rice yield

Popular rice varieties cultivated by our sample farmers are listed in Table 9. Among control households of the 2012 samples, Swarna was the most popular variety, occupying more than 30 per cent of the area under rice, followed by hybrid (which combines all hybrid varieties) and Lalat. Lalat is a modern rice variety released in 1988. (Detailed information about Lalat and other varieties is presented in Appendix G, Table G1.) Before the *kharif* planting season of 2012, the 2012 treatment households received Sahbhagi Dhan seeds. The area under Sahbhagi Dhan was 15.2 per cent 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 area of Swarna had increased to 31.5 per cent of the total area, which was comparable with 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 it. Before receiving Sahbhagi Dhan, the most popular rice variety among the 2013 treatment households was hybrid, occupying 14.6 per cent 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 Dhan, the areas under hybrid, Lalat and other varieties declined significantly, while the area under Swarna did not change significantly. As we will show later in this report, hybrid varieties and Lalat have short growth durations. Thus, it seems that farmers replaced short-duration rice varieties with Sahbhagi Dhan, another short-duration variety.

Table 9: Area under rice varieties grown in 2012 and 2013: treatment versus control

Rice variety	Treatment households			Control households		
	2012	2013	Diff.	2012	2013	Diff.
	% of cultivation area		Diff. in %	% of cultivation area		Diff. 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	Diff. in ha	ha	ha	Diff. 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	Diff. in ha	ha	ha	Diff. in ha
Total area (ha)	373.0	362.7	−10.3	421.1	412.2	−8.9

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

Table 10: Rice yield (tons per hectare): treatment versus control households/plots

	Treatment households			Control households		
	2012	2013	Diff.	2012	2013	Diff.
	t/ha (S.D.)	t/ha (S.D.)	Diff. [t-stat]	t/ha (S.D.)	t/ha (S.D.)	Diff. [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 sample						
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 sample						
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.).

The 2013 sample farmers had 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 hectare, while that of the 2012 control farmers was about 3.0 tons per hectare. This is as expected, because drought-prone areas were purposefully selected for area expansion. What is important is the comparison between the control and treatment farmers before the RCT intervention. In 2012, the average yield of the 2013 treatment farmers was 2.3 tons per hectare, which was not statistically different from that of the control farmers. This again confirms that the selection of the treatment farmers was implemented properly.

In 2013, the treatment farmers received Sahbhagi Dhan seeds. The average yield of Sahbhagi Dhan was only 1.5 tons per hectare, lower by more than 0.9 tons per hectare 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 was lower than that of the other rice varieties by 0.3 tons per hectare in 2012 and 0.6 tons per hectare in 2013.

7.2 Constructing a drought indicator

To investigate whether Sahbhagi Dhan performs better under drought conditions, we asked survey respondents to classify whether they experienced mild, severe or very severe drought conditions during the period of rice growth duration in the *kharif* season. Growth duration was divided into five periods – sowing to transplanting, early to tillering, panicle initiation, heading to flowering, and harvesting. Because exposure to high temperatures during the flowering period has been found to reduce rice yield (Matsui et al. 2000), we decided to focus on the drought condition during the heading to flowering period. Drought conditions during the harvest period also affect farmers' decisions on cultivating crops in *rabi* (the following agricultural season). Because these two periods are important in both rice yield and cultivation of *rabi* crops, and because the drought conditions of the two periods are highly correlated, we decided to combine the two periods.

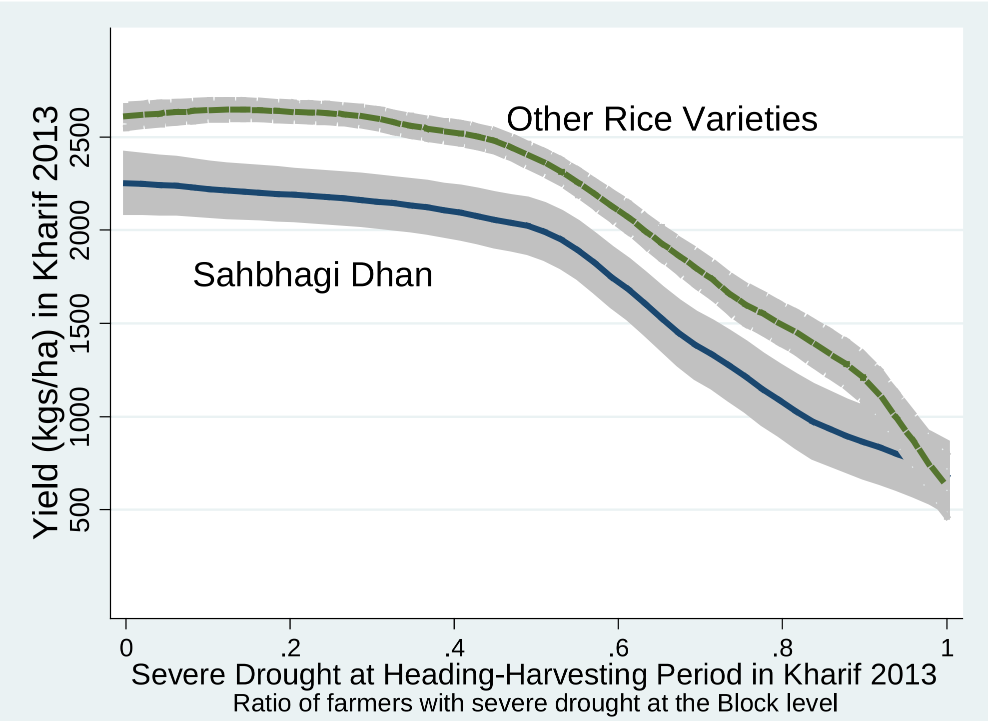
Drought perceptions may vary among farmers in a given area, even though they are exposed to the same weather conditions. Thus, we aggregated the individual drought perceptions to the block level (four villages were selected around block-level rainfall stations). Therefore, 4 villages at the block level (2 treatment and 2 control villages) should be exposed to the same drought conditions. However, because Sahbhagi Dhan is an early maturing rice variety, 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 used only the drought perceptions of the control farmers and aggregated up to the block level and applied this to both control and treatment farmers. As a result, we have created a drought index that is the proportion of (control) farmers who perceived severe drought during the heading to harvesting period.

7.3 Rice yield under drought

To examine the relationship between rice yield and drought conditions, we used the Karnel-weighted local polynomial smoothing technique and plotted the smoothed lines in Figure 5 for Sahbhagi Dhan and the other varieties.[2] As Figure 5 shows, we found that the yield of Sahbhagi Dhan is lower than that of the other varieties, even under drought conditions, although the difference between the two groups shrinks as the proportion of farmers who experienced drought increases and becomes close to 1. The yield of the other varieties remains flat above 2.5 tons per hectare while the proportion of farmers with severe drought is below 0.4. As the proportion increases beyond 0.4 and reaches 1, yield declines quickly to 0.5 tons per hectare. The yield of Sahbhagi Dhan is about 0.3 to 0.5 tons per hectare lower than the yield of the other varieties when the proportion of farmers with severe drought is below 0.4. However, yield declines to 0.5 tons per hectare as the proportion of farmers reaches 1, and the difference gap between the yield of Sahbhagi Dhan and the other varieties disappears.

[2] The graph was created using STATA.

Figure 5: Rice yield and severe drought during heading to harvesting period in *kharif* 2013



Note: The level of drought from heading to 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 2013 *kharif* season.

7.4 Cultivation of a *rabi* crop after *kharif* season

One major advantage of Sahbhagi Dhan is its short growth duration. In Table 11, 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, 17 weeks, which corresponds to 107 to 119 days.[3] Next is Lalat, at 17.7 weeks. The average growth durations of hybrid, IR64, Swarna and other minor rice varieties surpass 20 weeks. The average growth duration of Swarna, the most popular rice variety in the study region, is about 22 weeks. Thus, the difference in the length of growth duration between Swarna and Sahbhagi Dhan is about five weeks. In general, rice varieties with longer growth durations have higher yields. The typical planting week for Sahbhagi Dhan was the third week of July 2013 in the survey areas in eastern India. It was harvested after 17 weeks, during the first week of November.

From Table 11, it is clear that most of the rice varieties were planted during the second and third weeks of July. 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 – mostly *rabi*

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

crops, but including vegetables that were grown between *kharif* and *rabi* seasons – and the names of major second crops. After the harvest of Sahbhagi Dhan, about 20 per cent of the plots were used for growing a second crop (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 the following spring. Vegetables were mostly planted between *kharif* and *rabi* seasons; they provide additional income to rice farmers. Although Swarna is the most popular rice variety, only 3 per cent of its plots were allocated to second crops.

Table 11: 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

To investigate in greater detail, we calculated the percentage of plots with second crops for treatment and control households for 2012 and 2013 (Table 12). Among both groups, the percentage of plots with second crops increased from 2012 to 2013. Among the 2012 samples, however, cultivation of second crops is limited. For instance, less than 5 per cent of the plots had any second crops among the treatment households in 2012 and 2013. To cultivate crops during *rabi* season, farmers need to have some access to water for irrigation. Our survey data indicate that less than 5 per cent of the plots of the 2012 sample households had access to underground water irrigation through wells, compared with about 10 per cent of the 2013 sample.

Among the 2013 sample households, we find that the percentage of plots with second crops increases by 8.5 percentage points, from 15.5 per cent to 24 per cent, in plots in which the treatment farmers cultivated Sahbhagi Dhan in 2013. This is a before–after indicator in the same plots. In the other plots where other rice varieties were grown by both the treatment and control farmers, the percentage of plots with second crops also increased by about 5.5 percentage points. Thus, there seems to be an upward trend in cultivating second crops in the areas of the 2013 samples. However, it seems that the impact is larger after the cultivation of Sahbhagi Dhan.

Table 12: Percentage of households that cultivated *rabi* crops

	Treatment households			Control households		
	2012	2013	Diff.	2012	2013	Diff.
	% (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 sample						
Sahbhagi Dhan plots	3.4	3.2	−0.2	n.a.	n.a.	
	(18.3)	(17.6)	[0.14]			
Non-Sahbhagi Dhan 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 sample						
Sahbhagi Dhan plots	15.5	24.0	+8.5**	n.a.	n.a.	
	(36.2)	(42.8)	[3.83]			
Non-Sahbhagi Dhan 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]				

To see which crops were cultivated after Sahbhagi Dhan, we present the list of crops that farmers cultivated after the *kharif* season in Table 13. From 2012 to 2013, the total cultivation area expanded from 52 hectares to 75 hectares among the treatment farmers, while it increased by only 8.8 hectares among the control farmers. Among the 2013 treatment farmers, the area for pulses expanded significantly. The area under vegetables also increased, although the area share remains only at approximately 2 per cent.

Table 13: Area under crops grown in 2012 and 2013 *kharif*: treatment versus control

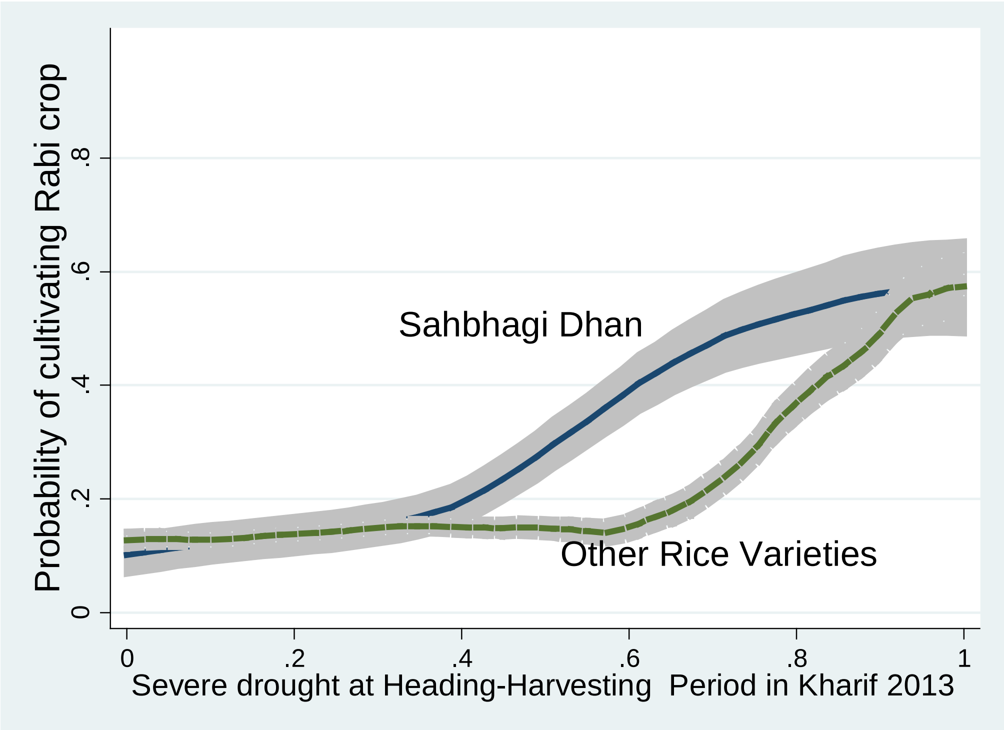
Rice variety	Treatment households			Control households		
	2012	2013	Diff.	2012	2013	Diff.
	% of cultivation area		Diff. in %	% of cultivation area		Diff. in %
2012 sample						
All crops	1.2	2.9	+1.7	11.5	8.2	−3.3
Fallow	98.8	97.1	−1.7	88.5	91.8	+3.3
	ha	ha	Diff. in ha	ha	ha	Diff. in ha
Total cultivated 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
Mung beans	2.5	2.4	−0.1	2.2	2.2	0
Vegetables	0.5	2.1	+1.6	0.3	1.4	+1.1
Pulses	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	Diff. in ha	ha	ha	Diff. in ha
Total cultivated area (ha)	52.4	74.5	+22.1	81.6	90.4	+8.8

To examine how drought in *kharif* affects the cultivation of second crops, we plotted the probability of cultivating second crops against the level of drought in Figure 6. We created graphs for the 2012 and 2013 samples separately because the results in Tables 12 and 13 clearly show that few farmers cultivated second crops in the 2012 sample areas. Figure 6 confirms this expectation.

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

From the descriptive analyses in this section, it appears that Sahbhagi Dhan has lower yield than other rice varieties but allows farmers to cultivate second crops after the *kharif* season. However, the analyses in this section do not control for other factors that affect rice yield. Although RCTs 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 choose plots for different varieties, including Sahbhagi Dhan, and their decisions might have affected the results on both yield and the 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 describe our estimation models.

Figure 6: Probability of cultivating a *rabi* crop and severe drought during heading to harvesting period during *kharif* 2013 at plot level among the 2013 sample farmers



7.5 Yield model

The first model in Table 14 is an ordinary least square model with the Sahbhagi Dhan intervention dummy only. Then, we add a drought dummy, measured at the block level (column 2) and the interaction term between the Sahbhagi Dhan dummy and the drought dummy (column 3). Finally, we present the plot-level fixed effects model (column 4). The estimated standard errors are clustered at the village level. In the estimation models, the Sahbhagi Dhan intervention dummies takes a value of 1 if farmers were selected in the treatment villages, regardless of their use of Sahbhagi Dhan. Thus, the estimated effects in the following tables represent the impact of the intention to treat. Nonetheless, because almost all treatment households had planted Sahbhagi Dhan, we expect to find little difference between the intention-to-treat impacts and the impacts among the treated.

The estimated coefficients of the Sahbhagi Dhan dummy is negative in all models, indicating that the yield of Sahbhagi Dhan is lower than that of other varieties by 0.3 to 0.4 tons per hectare. Drought, measured by the proportion of farmers who experienced severe drought during the heading and harvesting period in a *kharif* season, significantly reduces the rice yield. The magnitude of the estimated coefficient suggests that yield declines by 1.3 to 1.6 tons per hectare if the drought is severe enough for all farmers experiencing 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.

Table 14: Determinants of rice yield (RCT with fixed effects)

	Ordinary least square			Plot-level fixed effects model
Variables	(1)	(2)	(3)	(4)
	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
Sahbhagi Dhan (= 1)	−493.2***	−424.0***	−321.7**	−270.9**
	(91.8)	(85.8)	(132.5)	(−117.3)
Block-level drought indicator				
Heading/flowering period		−1,640.6***	−1,589.8***	−1,303.0***
		(176.9)	(186.1)	(111.0)
Heading/flowering period *x* Sahbhagi Dhan			−316.3	−378.5
			(269.8)	(−274.6)
Constant	2,442.7	2,915.1	2,900.5	2,928.6***
	(59.7)	(79.6)	(79.3)	(44.0)
R-squared	0.007	0.043	0.043	0.050
Number of plots				4,487
Observations	8,434	8,434	8,434	8,434

Note: The standard errors of the ordinary least square model are clustered at the village level.

7.6 Cultivation of *rabi* crops

As we divided the samples 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 the Sahbhagi Dhan dummy indicates that the probability of cultivating a second crop after the *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 a 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 indicates that the probability of cultivating second crops increases by 15 percentage points if all farmers in a block experience severe drought. Because such a severe drought will cause a significant crop loss in rice, farmers may believe it is necessary to compensate for crop loss by cultivating second crops after the *kharif* season. As we find in Figure 6 the impact of a severe drought on the probability of cultivating second crops is higher in Sahbhagi Dhan plots. This is probably because the variety has a short growth duration, which allows farmers to cultivate second crops immediately after the harvest of Sahbhagi Dhan during 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 increases by about 15 percentage points in Sahbhagi Dhan plots when all farmers experienced severe drought.

Among the other variables included in the estimation model, irrigation dummies have large coefficients (Table 15). 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 have difficulties cultivating crops after the *kharif* season if they do not have access to irrigation.

Table 15: Determinants of cultivating *rabi* crops among the 2013 sample

Variables	Probit model[4] (1)	Plot fixed effects model (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 Sahbhagi Dhan			
Heading/flowering period *x* Sahbhagi Dhan			0.146**
			(2.464)
Plot characteristics			
Plot size in ha	0.0121		
	(1.505)		
Crop establishment: broadcasting	0.0754***		
Base group is transplanting	(5.136)		
Irrigation: underground water (= 1)	0.218***		
	(12.09)		
Irrigation: surface water (= 1)	0.206***		
	(12.03)		
Lowland plot (= 1)	0.0140		
	(1.053)		
Upland plot (= 1)	−0.0350***		
	(−3.289)		
Household characteristics			
Number of bulls	−0.0124***		
	(−3.044)		
Number of buffaloes	−0.00543		
	(−0.695)		
Household head: age	0.000612		
	(1.601)		
Household head: education	0.00227**		
	(2.069)		
Scheduled caste/tribe	−0.0125		
	(−0.842)		
Other backward class	0.0533***		
	(3.457)		
Year 2014 dummy	0.0589***	0.0610***	0.0652***
	(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

Note: The numbers of children and adults were included in the model, but the results are not reported here.

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

8. Discussion

Drought-tolerant rice varieties such as Sahbhagi Dhan have been developed to reduce yield losses caused by drought; however, few studies have evaluated the performance of Sahbhagi Dhan among farmers. We used an RCT to evaluate the performance of this variety by providing Sahbhagi Dhan seeds to randomly selected farmers in treatment villages in either 2012 or 2013. To measure the impact of drought on rice production, we created a drought index of the proportion of farmers experiencing severe drought during the heading and harvesting period in a *kharif* season.

There are at least three major limitations in this study. First, in addition to the drought index based on farmers' perceptions, we collected rainfall data from 83 block-level rainfall stations. The rainfall data from the 83 stations was were recorded poorly and were missing data points. After comparing these data with secondary rainfall data and examining them against farmers' perceptions on drought conditions, we decided not to use the data in this analysis. It is also difficult to measure drought conditions, since moisture levels across plots were different even within a single village. Therefore, we chose to rely on the drought index based on farmer perceptions. Second, during the *kharif* season in 2013, the main agricultural season for our RCT, severe cyclones occurred in our study areas, damaging rice production, including Sahbhagi Dhan plots. It seems that the damages caused by the 2013 cyclones have made it difficult for us to identify the impact of Sahbhagi Dhan under drought. Third, without clearly identified the impacts of Sahbhagi Dhan on rice yield under drought, we could not analyze consequential impacts from the mitigated production losses on household welfare indicators. Despite these limitations, the findings summarized below suggest some important policy implications.

The findings in this report clearly show that the drought measured by the index significantly reduces rice yield. The magnitude of the estimated coefficient suggests that yield declines by 1.3 tons per hectare if the drought is severe enough for all farmers. We found that the yield of Sahbhagi Dhan is lower than that of other varieties, by 0.3 to 0.4 tons per hectare. We found little evidence that Sahbhagi Dhan is more tolerant of drought than other rice varieties.

Exposure to high temperatures during rice flowering can greatly reduce pollen viability, which leads to yield loss. Because Sahbhagi Dhan is an early maturing rice variety, it flowers earlier and becomes vulnerable to high temperatures at different times than other rice varieties, especially late-maturing ones. This makes Sahbhagi Dhan drought-tolerant when high temperatures occur after Sahbhagi Dhan completes its flowering period and as other varieties enter their flowering period. For our study, the timing of high temperatures in 2012 and 2013 *kharif* seasons may not have been favorable for Sahbhagi Dhan. Therefore, it might be premature to draw conclusions on the variety, and we need to continue monitoring its performance.

The short duration of Sahbhagi Dhan helps farmers to cultivate crops after the *kharif* season in India. The findings in this report indicate that the probability of producing second crops after *kharif* is higher by 3 percentage points in Sahbhagi Dhan plots than in other plots. The results also show that the probability of cultivating second crops is higher when farmers experience drought during *kharif*, and that the probability becomes even higher in Sahbhagi Dhan plots. After drought, farmers may feel the need to compensate for crop losses due to drought by cultivating more crops after the season. We found this benefit only in areas where farmers could cultivate crops after *kharif* (where it is possible to produce double crops).

The findings in this report suggest targeting strategies for Sahbhagi Dhan. The main benefit of Sahbhagi Dhan appears to be its short growth duration, which helps farmers in areas 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 to become less vulnerable to drought and other shocks during *kharif* by diversifying income sources.

Experiments in farmers' fields are different from agronomic experiments on research stations. Although we do not observe Sahbhagi Dhan drought tolerance in this report, it can become tolerant under certain drought conditions. Its drought tolerance therefore continues to be monitored among farmers.

9. Specific findings for policy and practice

Based on the findings in this report, we draw the following policy implications and practices:

1. Targeting strategies for Sahbhagi Dhan: Based on our findings, the main benefit of Sahbhagi Dhan appears to be its 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 to become less vulnerable to drought and other shocks during *kharif* by diversifying income sources.
2. In this project, we could not confirm that Sahbhagi Dhan is drought tolerant. There are several reasons for this finding. Unlike experimental fields, where many factors are controlled, unexpected shocks occur in farmers' fields. The large cyclone in one of the survey years (2013) destroyed the rice production of respondents. It is therefore recommended to continue monitoring the performance of Sahbhagi Dhan.
3. In this report, we found a large negative impact of drought on rice production. To mitigate losses due to drought, new drought-tolerant rice varieties need to be developed, especially varieties with high yields. Although farmers are aware of the danger of drought, they face a dilemma in choosing between a high-yielding variety and a drought-tolerant one with a yield penalty. Advanced breeding technology is expected to solve this dilemma. There should be a continuous investment in rice breeding research for drought-tolerant and other stress-tolerant rice varieties.

Appendix A: Findings from qualitative survey

Before we conducted the quantitative survey, we conducted site visits to the target areas and a qualitative survey, interviewing farmers who had grown Sahbhagi Dhan. We learned the following:

1. Farmers appreciate the short growth duration of Sahbhagi Dhan, which ranges from 90 to 110 days, compared with 100 to 120 days for other rice varieties that are popular in the target areas. The short duration of Sahbhagi Dhan allows farmers to prepare for *rabi* crops, which are cultivated after *kharif* rice. Previous studies have found that the early sowing of *rabi* crops, such as maize and wheat, increases their productivity. Some farmers even produced vegetables between the *kharif* and *rabi* seasons.
2. Although farmers identified advantages of Sahbhagi Dhan, such as its drought tolerance and short duration, compared with other rice varieties, they are concerned about the possible yield penalty under normal weather conditions. Under normal weather conditions, the average yield of other rice varieties is often higher than the average yield of Sahbhagi Dhan. Thus, farmers face a trade-off between the advantages of Sahbhagi Dhan and the possible yield penalty.
3. Central to our earlier expectation, farmers rarely exchange rice seeds among themselves. The main method of acquiring new rice seeds is to buy from seed dealers or wait to receive new rice seeds from a non-governmental organization or from extension workers. Only some progressive farmers exchange their knowledge about new rice seeds and other agricultural technologies among themselves.

Based on the findings from qualitative interviews with farmers, we designed a quantitative questionnaire to capture: (1) the benefits of short duration; (2) the trade-off between the advantages and yield penalty; and (3) the possible constraints to farmer-to-farmer seed exchange.

Appendix B: Sample design

In May and June 2012, IRRI conducted an RTC by randomly selecting 128 treatment villages and 128 control villages in one district in Odisha and two districts in West Bengal. In each treatment village, 5 farmers were randomly chosen to receive a minikit with 5 kilograms of Sahbhagi Dhan seeds, accompanied by a brochure with instructions for cultivation. To ensure compliance with the randomization in selecting treatment farmers, the enumerators, with village officers, created a list of 100 households in the village and telephoned the IRRI New Delhi office to obtain 5 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 5 farmers per village, who were all interviewed in multiple surveys.

In 2013, partly with research funds from the International Initiative for Impact Evaluation (3ie), we expanded the study area by: (1) taking 79 sample villages out of the 256 sample villages in the 2012 RTC; and (2) adding 252 villages across 6 more districts in Odisha and Jharkhand (Table B1). The expansion of the study area was decided to capture a larger variation in drought conditions across different ecological zones.

For the additional samples in 2013, we used the following sampling procedure:

1. Purposely select nine drought-prone districts;
2. Randomly select blocks in each sample district; and
3. In each block, identify a rainfall station and listed nearby villages. Of the listed villages, four were randomly chosen. At the same time, daily rainfall data were collected from the nearby rainfall station. Daily rainfall data was updated periodically. Of the 4 villages per rainfall station, we randomly selected 2 treatment villages and 2control villages.

From each sample village, we randomly selected five households. We followed the same protocol used in 2012 to randomly select five farmers per village. After the household selection, we conducted a household survey from March to May 2013. At the time of the survey, respondents were not informed about their treatment status. Only several weeks after the household survey did treatment households receive Sahbhagi Dhan minikits.

In the five-month period of April to August 2014, we conducted a follow-up survey of the same sample households. In some areas, especially Jharkhand, the survey activities were delayed because of India’s national election, which took place in April and May 2014. The survey was completed in August 2014. In Table B1, we present the sample distribution across research areas.

Table B1: Sample farmers in 2012, 2013 and 2014 surveys

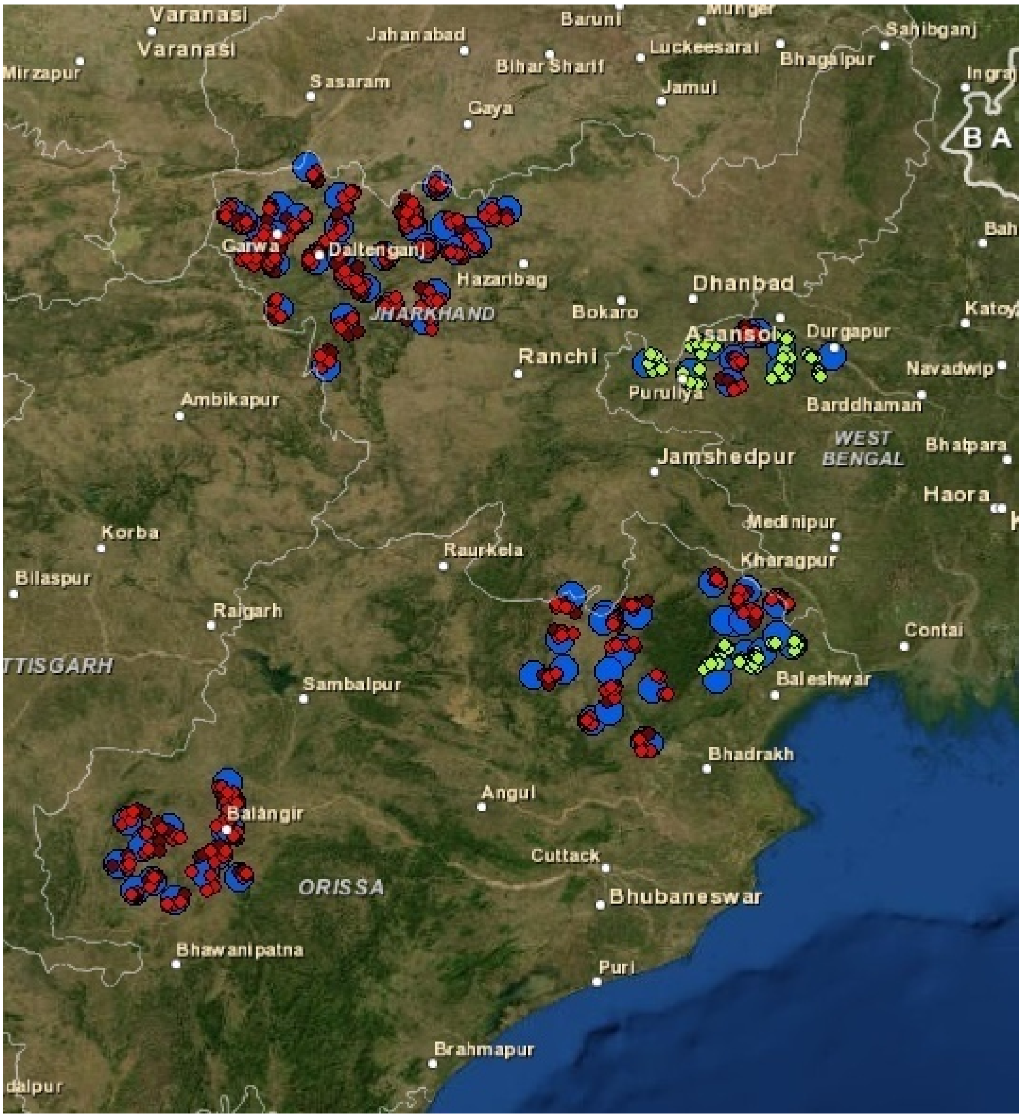
State	District	Blocks	Villages	Farmers		
				2012	2013	2014*
		Number (2012 sample)	Number (2012 sample)	Number	Number (2012 sample)	Number (2012 sample)
Jharkhand	Gharwa	10	40		200	158
	Palamu	8	32		160	177
	Latehar	5	20		100	118
	Chatra	8	32		160	75
Odisha	Balangir	14	56		280	269
	Keonjhar	6	24		120	120
	Mayurbhanj	8 (6)	74 (42)	210	370 (210)	370 (210)
West Bengal	Purulia	4 (3)	37 (16)	105	185 (105)	183 (101)
	Bankura	3 (3)	21 (21)	105	105 (105)	101 (102)
Total		**66 (12)**	**336 (79)**	**420**	**1,680**	**1,571**

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

Table B1 shows the distribution of the samples across nine districts in three states. Of the 331 total villages, 79 were from the 2012 sample, with an additional 252 chosen in 2013. The survey sample included 420 farmers from the 2012 survey and 1,260 farmers chosen in 2013, for a total of 1,680 households. Half of the sample villages and half of the sample households were in the treatment group. Of 1,680 households, 1,571 households were re-interviewed in 2014. However, interviews with some households in Jharkhand were delayed and their data were not available at the time of writing this report. Their data will be added to the database later.

In Figure B1, 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 would 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. Figure B1 also shows the locations of rainfall stations (blue circles), the 2013 sample villages and the 2012 sample villages. It clearly shows that four villages are selected for each rainfall station.

Figure B1: Total samples with weather stations (blue), 2013 sample villages (red) and 2012 sample villages (green)



Appendix C: Pre-analysis plan

By using the data from the RCT of Sahbhagi Dhan, we plan to analyze the impact of adopting Sahbhagi Dhan on various outputs. Because Sahbhagi Dhan is a drought-tolerant rice variety, under normal weather conditions we do not expect to find a significant impact from adopting it. Thus, to identify differential impacts of adopting Sahbhagi Dhan under drought conditions, we need to first identify drought conditions and then isolate and estimate the impacts under various degrees of drought conditions. However, identifying drought conditions is not an easy task, because it is difficult to define drought.

In our analysis, we use several definitions of drought through daily rainfall data and farmers' subjective perceptions of drought. If we define drought and create an indicator for drought, a general regression model should take the form of the following regression model:

$$Outcome_{pt} = \beta_0 + \beta_1 Treatment_{pt} + \beta_2\, Drought_{bt} + \beta_3 Treatment_{pt} * Drought_{bt} + \gamma_t + \mu_p + \varepsilon_{pt}$$

plot p, block b, year t

$Treatment_{bt}$ is a dummy variable for treatment households.

Drought is a dummy variable that takes 1 if block *b* experienced drought in year *t.*

Clustering is done at the block level (preferred) or village level.

We will try different ways of identifying drought and may use a continuous variable to specify a degree of drought.

By using regression models, we will try to test the following research questions:

- What is the yield advantage of drought-tolerant rice on average and as a function of drought? How does its yield compare with the yield of other (short- and long-duration) varieties?
- Does drought-tolerant rice enable farmers to increase their cropping intensity?

Appendix D: Power calculation

The power calculations are based on survey data collected by IRRI in 2011. Yield data are available for 570 farmers living in six villages. Average yield is 4,269 kilograms per hectare and has a standard deviation of 1,641 kilograms. We vary the intra-cluster correlation from 0.3 to 0.5 and calculate the required number of villages necessary to detect a 10 per cent increase in yield, which is equivalent to a 0.26 standard deviation. Using 5 farmers per village, the required number of villages is 272 if the intra-cluster correlation is 0.3, and 371 if the intra-cluster correlation is 0.5. This is lower than the 512 villages proposed for the experimental design. Conversely, using an intra-cluster correlation of 0.5, 5 farmers per village and 512 villages as inputs, the power calculation shows that any standard effect size that exceeds 0.19 can be detected.

Appendix E: Econometric methods and regression specifications

In this appendix, we estimate two models: (1) the rice yield model; and (2) the determinants of cultivating second crops. Both models are estimated at the plot level. With panel data, we estimate both models with plot-level fixed effects. This helps us to 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, then 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 (kilograms per hectare) of plot *s* of farmer *i* of block *j* at time *t*; $S_{sijt}$is a Sahbhagi Dhan dummy variable that takes a value of 1 if Sahbhagi Dhan is cultivated in 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 includes other variables of household characteristics.

In the second model, the dependent variable is a dummy variable that takes a value of 1 if second crops are cultivated in the same plot. Because the dependent variable is a dummy variable, the model becomes a linear probability model with plot-level fixed effects. We will compare the basic model with the results from probit if the results in the 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. However, it could be correlated with unobserved characteristics of plots, because the treatment farmers can decide in 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 the surveys to clearly identify the plots that were mentioned in the 2012 survey. Because the interviews were conducted by using a computer-assisted personal interview software package, Surveybe, the enumerators could see plot information 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 on *kharif* 2013 production of the same plots.

Appendix F: Monitoring plan

The RCT protocols were implemented by our counterparts in the fields. Because of long-term collaborations, our local NGOs counterparts like IRRI understand our protocols and have regular communication with us on this and other projects, which makes it easy to monitor their activities. Our counterparts contacted us when they were faced with any questions in the field. To monitor RCT protocols, we monitored computer-based interview files as interviews were conducted, along with the implementation of the RCT – i.e. distributions of Sahbhagi Dhan seeds.

The randomization of the treatment villages was examined immediately after the data were collected from treatment and control farmers. Immediately after collecting household data, we found no difference in the average values of all indicators of the treatment and control villages.

Appendix G: Descriptive statistics

Popular rice varieties are listed according to the number of plots under these varieties in Table G1. Among control households, Swarna is the most popular rice variety, occupying about 20% of all rice plots cultivated by the control households, followed by hybrid (which combines all hybrid varieties) at 12.9%, Lalat (10.6%), IR64 (5.7%) and so on.

Among treatment households, Sahbhagi Dhan was the most popular rice variety because it was given to the treatment households in either 2012 or 2013. Sahbhagi Dhan occupies more than 30% of the plots that the treatment households cultivated in *kharif* 2013, followed by Swarna (19.4%), Lalat (9.0%), hybrid (4.9%) and so on.

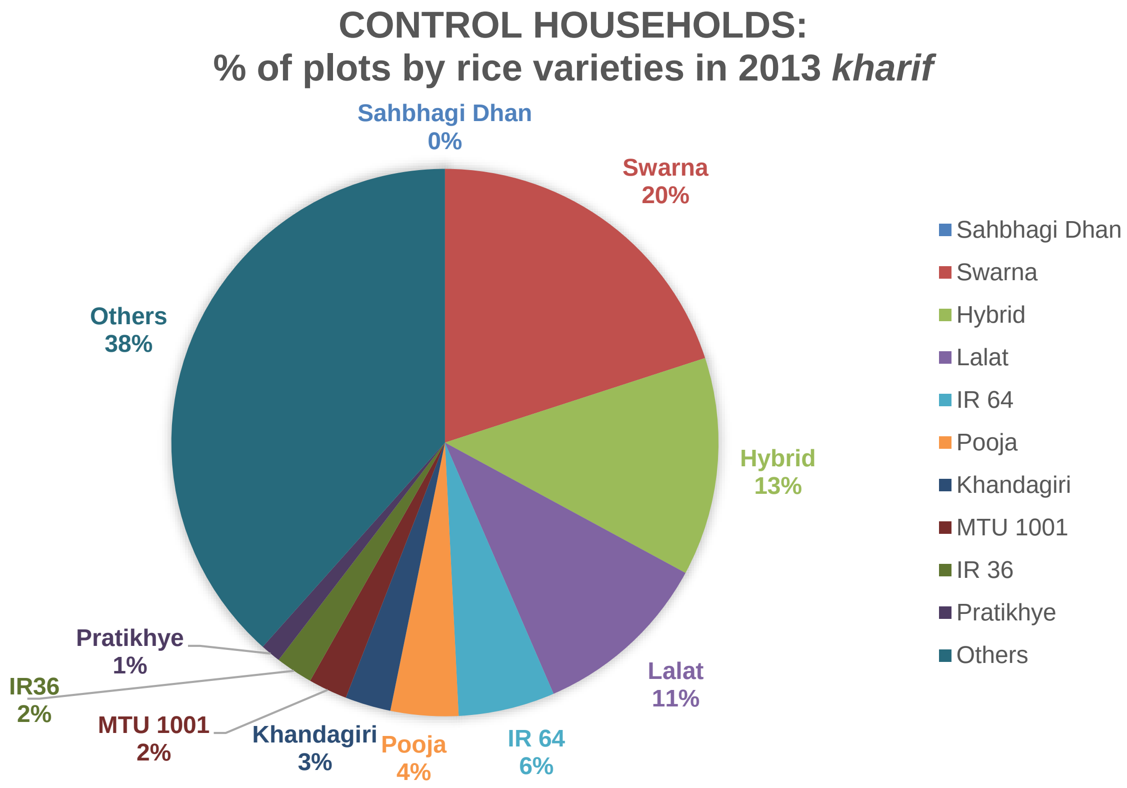
The same information is depicted in Figure G1, in which it is clear that fewer plots were allocated to hybrid rice among the treatment households (5%) than among the control households (12.9%). Also, fewer plots were allocated to 'others', which includes minor rice varieties, among the treatment households (28.8%) than among the control households (38.1%). Therefore, it seems that the treatment households have replaced Sahbhagi Dhan with hybrid and minor rice varieties, while keeping plots for other major rice varieties, such as Swarna, Lalat and Pooja.

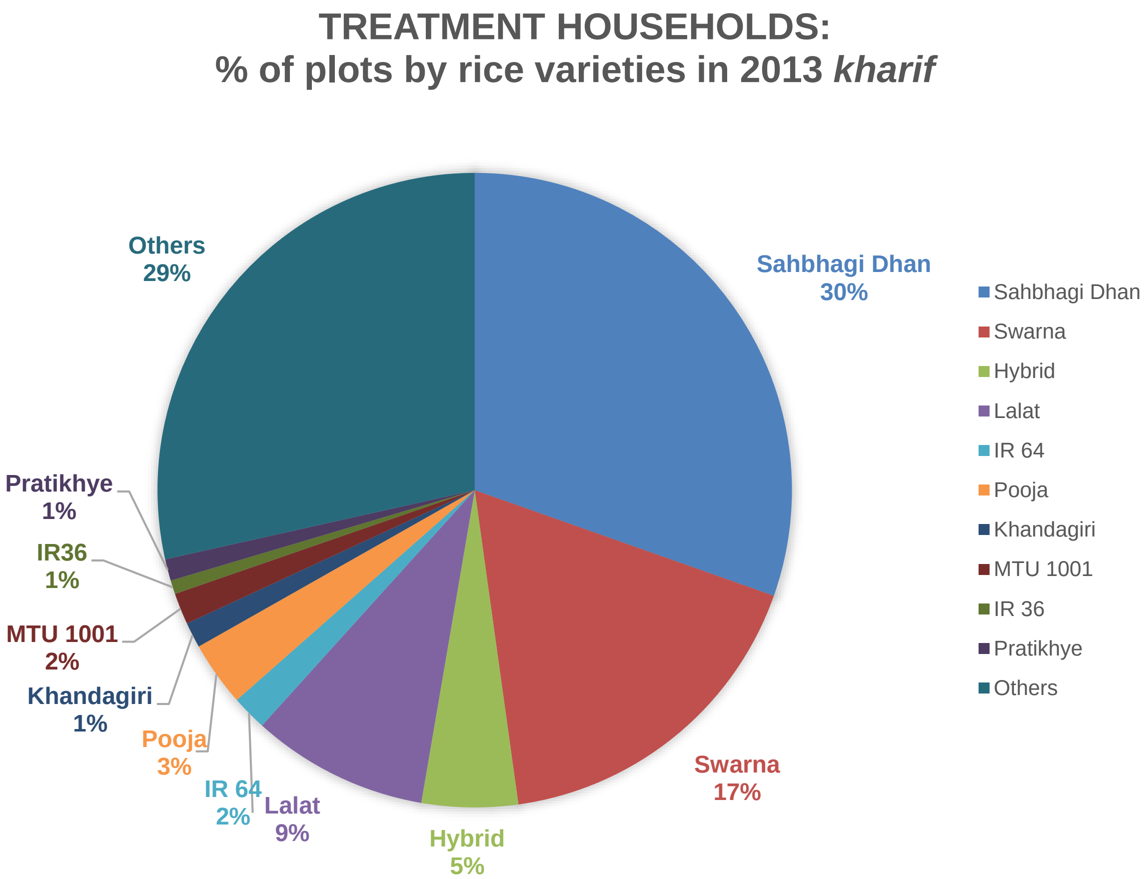
Table G1: Popular rice varieties among treatment and control households

Control households			**Treatment households**		
Rice variety	**Number of plots (%)**	**Average plot size in ha**	**Rice variety**	**Number of plots (%)**	**Average plot size in ha**
Swarna	344 (20.0)	0.27	**Sahbhagi Dhan**	**783 (30.4)**	**0.19**
Hybrid	220 (12.9)	0.28	Swarna	514 (19.4)	0.23
Lalat	181 (10.6)	0.25	Lalat	233 (9.0)	0.19
IR64	98 (5.7)	0.29	Hybrid	125 (4.9)	0.24
Pooja	68 (4.0)	0.37	Pooja	86 (3.3)	0.32
Khandagiri	46 (2.7)	0.27	IR64	45 (1.8)	0.23
MTU 1001	40 (2.3)	0.30	MTU 1001	42 (1.6)	0.23
IR36	37 (2.2)	0.35	Khandagiri	33 (1.3)	0.25
Pratikhye	21 (1.2)	0.25	Pratikhye	29 (1.1)	0.25
Others	651 (38.1)	-	Others	742 (28.8)	-
Total	1,706 (100)	0.23	Total	2,632 (100)	0.17

Note: This table shows mean values with standard deviations in parentheses. Varieties that are grown by at least 30 farmers are included.

Figure G1: Percentage of plots allocated for different rice varieties during *kharif* 2013





Next, we present the average yields of rice varieties. The average yield of Sahbhagi Dhan is 1,573 kilograms per hectare, lower than that of other varieties. Notably, however, many households, including Sahbhagi Dhan growers, experienced crop damage caused by different stresses. Respondents indicated that more than 82 per cent of the Sahbhagi Dhan plots were damaged by various stresses during *kharif* 2013. When we divided the sample based on farmers' perceptions about damage, we found that the average yield of Sahbhagi Dhan was 3,030 kilograms per hectare without any damage, whereas it is only 1,266 kilograms per hectare with damage.

Table G2: Popular rice varieties, yield with and without damage

Rice variety	Number of plots	Yield (kg/ha)	Yield (kg/ha) with damage: No	Yield (kg/ha) with damage: Yes	Percentage of damaged plots
	Number	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
Sahbhagi Dhan	**787**	**1,573** (1,544)	**3,030** (1,810)	**1,266** (1,287)	**82.6**
Swarna	858	2,844 (1,677)	3,779 (1,364)	2,422 (1,652)	73.8
Lalat	414	2,487 (1,524)	3,429 (1,216)	2,011 (1,442)	66.4
Hybrid (specify)	345	2,029 (1,881)	3,228 (1,569)	1,797 (1,849)	83.8
Pooja	154	2,739 (1,694)	3,498 (1,667)	2,445 (1,618)	72.1
IR64	143	1,541 (2,006)	3,969 (2,125)	1,027 (1,560)	82.5
MTU 1001	82	3,133 (1,667)	3,938 (1,507)	2,563 (1,548)	40.0
Khandagiri	79	1,656 (1,304)	2,374 (1,443)	1,474 (1,212)	79.7
IR36	56	845 (1,367)		845 (1,367)	100
Other (specify)	1,190	1,953 (1,667)	3,495 (1,635)	1,653 (1,499)	83.7

Note: This table shows mean values with standard deviations in parentheses. Varieties that are grown by at least 30 farmers are included.

The average yield of the most popular rice variety, Swarna, was 2,844 kilograms per hectare in 2013. The average yield of Swarna is 3,779 kilograms per hectare without any damage and 2,422 kilograms per hectare with damage. In all three conditions, therefore, the average yield of Swarna is about 700 kilograms per hectare higher than that of Sahbhagi Dhan. The average yields of other varieties are also presented in Table G2.

Growth duration and yield

One major advantage of Sahbhagi Dhan is its short growth duration. In Table G3, 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. Sahbhagi Dhan has the shortest duration (17 weeks). Next is Lalat (17.7 weeks), followed by Khandagiri (18 weeks) and

MTU 1001 (19.3 weeks). Swarna has a long duration, at about 22 weeks. Thus, the difference in the length of growth duration between Swarna and Sahbhagi Dhan is about five weeks, more than a month. In general, rice varieties with a longer duration have a higher yield.

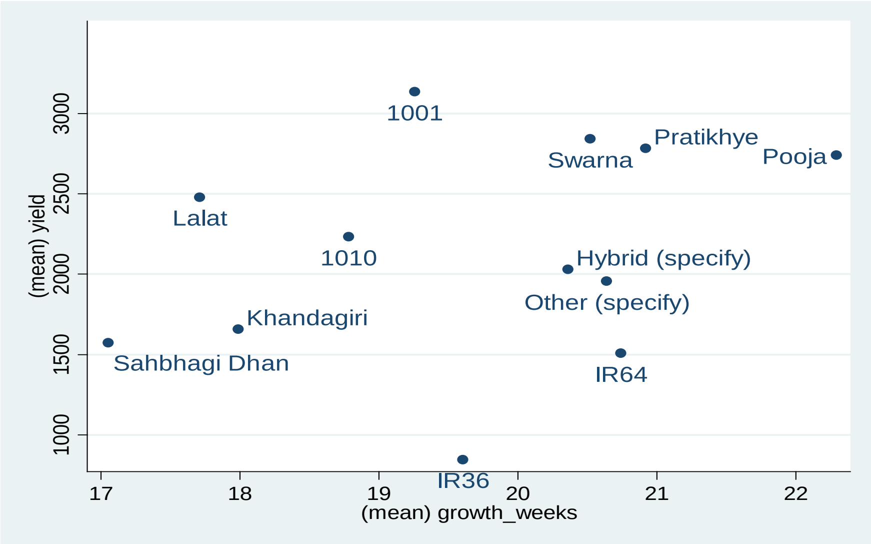
Table G3: Rice growth duration, planting month and harvesting month in 2013

Rice variety	**Weeks (days)**	**Planting month & week**				**Harvesting month & week**					
	Weeks (days)	July				November					Dec.
		2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	1st
Sahbhagi Dhan	17.1 (107−119)										
Lalat	17.7 (114−126)										
Khandagiri	18.0 (114−126)										
MTU 1001	19.3 (121−133)										
IR36	19.6 (128−140)										
Hybrid	20.4 (128−140)										
IR64	20.7 (135−147)										
Swarna	20.9 (135−147)										
Pooja	22.3 (142−154)										
Other (specify)	20.6 (135−147)										

The typical planting week for Sahbhagi Dhan was the third week of July 2013 in the survey areas in eastern India. It was harvested after 17 weeks, during the first week of November. Because we asked respondents to identify the planting week and the harvesting week for each plot, the actual duration in days should be less than the number of days in the duration in weeks. For example, a farmer might have planted a variety on Saturday of week 2 in July and harvested on Sunday of week 1 of November. In this case, the actual growth length in days is 107 days (15 weeks times 7 days, plus 2 days). This would be the minimum number of days within 17 weeks. The maximum number of days is 119 days. Thus, the length of the growth duration of Sahbhagi Dhan is somewhere around 107 days to 119 days. For other lengths in weeks, we also calculated possible days and indicated this in the table.

Because of different durations, it is more meaningful to compare yield while controlling for the growth duration of different rice varieties (Figure G2). In this figure, it is clear that Sahbhagi Dhan has a low yield, even after controlling for growth duration. With less than a week's difference, Lalat has an advantage of about 1 ton per hectare over Sahbhagi Dhan.

Figure G2: Average rice yield by growth duration



Description of damage

During *kharif* 2013, many respondents experienced damage to their crops. Table G4 presents the percentages of rice plots that suffered damage from different causes. Cyclone damaged about 40 per cent of the plots. The severity of the damage was high at about 70 per cent (note that 100 % indicates a complete loss), leaving the average rice yield at 1,886 kilograms per hectare.

The percentage of plots suffering from drought is lower, at about 19 per cent. However, the severity of the damage was highest (76.5%) among all damage types. The average rice yield was 1,358 kilograms per hectare. Submergence and crop disease follow.

Table G4: Types of damage in *kharif* 2013

Type of damage	Percentage of plots	Degree of damage	Rice yield (kg/ha)
	%	%	Mean (S.D.)
Cyclone	39.9	67.9	1,886 (1,539)
Drought	29.2	76.5	1,358 (1,550)
Submergence	27.1	50.1	2,013 (1,539)
Crop disease	26.2	44.4	2,128 (1,542)
Any damage	77.5	51.1	1,768 (1,573)
No damage	22.5	0	3,508 (1,535)

Some of the stresses listed in Table G4 occur at the same time. For instance, a cyclone can cause flooding in the same area. Often, crop diseases occur when rice is weakened by one stress, such as drought or flooding. Thus, Figure G3, the proportion of rice plots is listed according to multiple stresses (also described in Table G5). The most frequent case is cyclone alone (15.2%), followed by cyclone and submergence (14.7%). Because a cyclone can cause flooding, we can safely assume that submergence was caused by cyclone. Thus, combined, 29.9 per cent of the rice plots in 2013 were damaged by cyclones. The next most frequent stress was drought. Drought alone affected about 15 per cent of the rice plots. This was followed by drought and crop disease (8.6%).

Figure G3: Multiple damage in rice plots in 2013 *kharif*

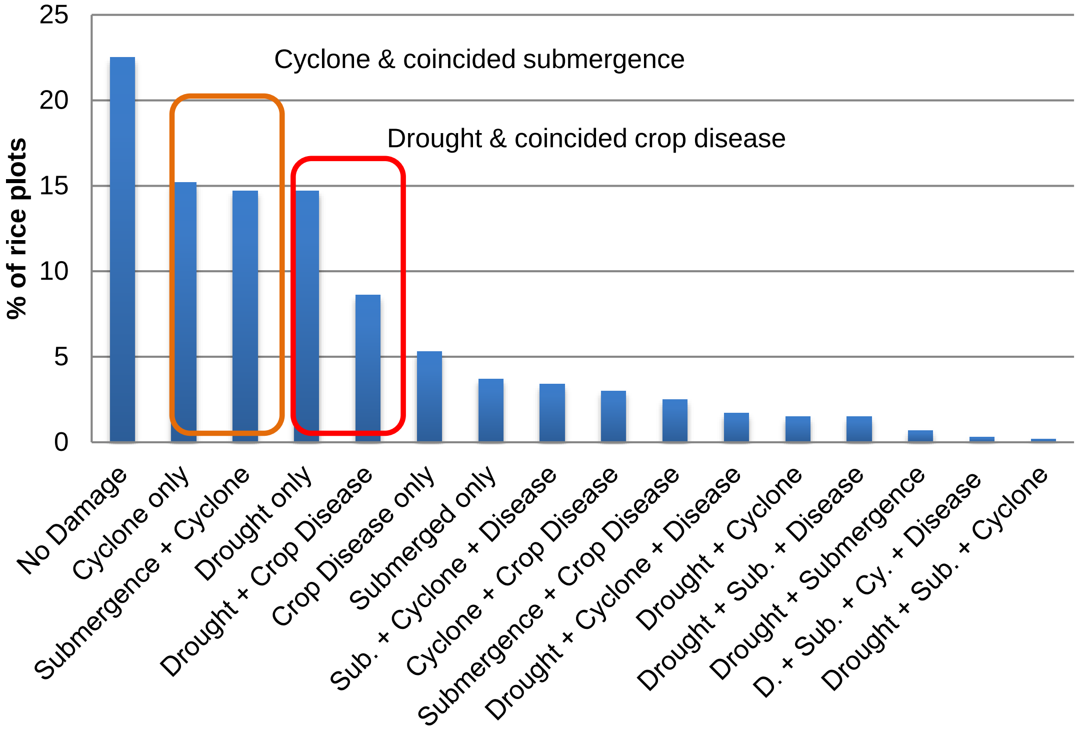


Table G5: Combination of stresses in *kharif* 2013 and average yield

Type of damage	Percentage of plots	Degree of damage	Rice yield (kg/ha)
	%	%	Mean
No damage	22.5	0	3,508
Drought and related damage			
Drought only	**14.7**	**49.2**	**777**
Drought + crop disease	**8.6**	**39.7**	**1,961**
Drought + submergence	0.7	39.5	2,075
Drought + cyclone	1.5	52.7	1.637
Drought + sub. + cyclone	0.2	49.0	1,715
Drought + cyclone + disease	1.7	44.3	1,770
Drought + sub. + disease	1.5	40.4	2,221
D. + sub. + cy. + disease	0.3	29.5	2,612
Cyclone and related damage			
Cyclone only	**15.2**	**43.4**	**1,966**
Submergence + cyclone	**14.7**	**58.1**	**1,780**
Sub. + cyclone + disease	3.4	44.2	2,170
Cyclone + crop disease	3.0	51.9	1,817
Other damage			
Crop disease only	5.3	43.8	2,455
Submergence only	3.7	72.8	2,374
Submergence + crop disease	2.5	38.5	2,456

Cultivation of second (*rabi*) crop after *kharif* season

From Table G6, it is clear that most of the rice varieties were planted during the second and third weeks of July. Sahbhagi Dhan, Lalat and Khandagiri were then harvested during the first and second weeks of November, making the rice fields available for next crops. To investigate this advantage, we list the typical week of harvesting, the proportion of plots with a second crop (which was mostly *rabi* crops but included vegetables that were grown in between *kharif* and *rabi* seasons) and the names of major second crops.

The list of varieties in Table G6 is sorted by the timing of the harvest. After the harvest of Sahbhagi Dhan, about 20 per cent of its plots were used to grow a second crop. The list of second crops after Sahbhagi Dhan includes wheat (53 cases), pulses (43) and vegetables (31). Early sowing of wheat is considered to increase its yield because it can avoid the terminal heat of its harvesting time in the next spring. Vegetables were mostly planted between the *kharif* and *rabi* seasons; they provide additional income to rice farmers. Some of the other varieties listed in Table G6 also have a high proportion of their plots allocated to a second (*rabi*) crop.

Although Swarna is the most popular rice variety, only 9.4 per cent of its plots were allocated to second crops. In many areas, notably in Odisha, farmers produce one crop per year. This reduces their annual crop income. Thus, Sahbhagi Dhan has an advantage over Swarna in this regard.

Table G6: Typical harvesting week and cultivation of second (*rabi*) crop in 2013

Rice varieties	Harvest month and week	Cultivated second crop after *kharif* 2013	Major second crops
		%	Crop name (number of plots)
Sahbhagi Dhan	Nov./1st week	19.9	Wheat (53), pulses (43), veg. (31)
Khandagiri	Nov./1st week	2.5	Too few
Lalat	Nov./2nd week	4.2	Too few
IR36	Nov./3rd week	41.1	Pulses (11), wheat (6)
Hybrid	Nov./3rd week	29.6	Wheat (62), pulses (13), veg. (13)
Pooja	Nov./3rd week	16.2	Pulses (16)
MTU 1001	Nov./4th week	13.4	Too few
MTU 7029	Nov./5th week	3.0	Too few
IR64	Dec./1st week	39.4	Wheat (26), pulses (17)
Swarna	Dec./1st week	9.4	Pulses (34), mung bean (15)
Other (specify)	Nov./4th week	12.0	

Experience growing Sahbhagi Dhan

Not all treatment households produce Sahbhagi Dhan continuously. After testing it in the first year, some treatment households decided not to plant it the next year. Table G7 describes the continuous use of Sahbhagi Dhan over years among treatment households. Among 299 treatment households that received Sahbhagi Dhan seeds in 2012, only 48 per cent cultivated it again in 2013. When asked about their plan to cultivate it in 2014, about 42 per cent of the 2012 treatment households indicated that they were planning to cultivate Sahbhagi Dhan in *kharif* 2014. Among 573 treatment households that received Sahbhagi Dhan seeds in 2013, 21 did not cultivate it in 2013. When asked about their plan to plant Sahbhagi Dhan in 2014, about 62 per cent of the 2013 treatment households indicated that they planned to use it in *kharif* 2014. Therefore, the dropout rate among both 2012 and 2013 treatment households is quite high.

Table G7: Use of Sahbhagi Dhan among treatment households over time

Treatment status	Treatment households	Cultivated Sahbhagi Dhan in 2012	Cultivated Sahbhagi Dhan in 2013	Plan to cultivate Sahbhagi Dhan in 2014
	Number (%)	Number (%)	Number (%)	Number (%)
2012 treatment households	299 (100)	299 (100)	143 (47.8)	125 (41.8)
2013 treatment households	573 (100)	n.a.	552 (96.3)	356 (62.1)

To investigate the reasons for the continuous or discontinuous use of Sahbhagi Dhan, we asked treatment households for their top three reasons for the continuous (or discontinuous) use of Sahbhagi Dhan. We find that, among the 2012 treatment households, high yield of Sahbhagi Dhan was the top reason for their continuous use of it (Table G8). Of 143 treatment households that received Sahbhagi Dhan seeds in 2012 and cultivated it again in 2013, 122 indicated high yield as one of the top three reasons for their continuous use in 2013. Short duration is the second reason for its continuous use, followed by good taste/cooking quality. Drought tolerance was cited by 68 households.

Among the treatment households that received Sahbhagi Dhan seeds in 2012 but did not cultivate it in 2013, we find that the top reason for discontinuous use was ‘No seeds left due to crop damage’, followed by a similar reason (‘No seeds were left due to consumption’). This suggests that after losing the seeds to damage or consumption, they did not have access to Sahbhagi Dhan seeds.

The same questions were asked of the 2013 treatment households. The results in Table G9 show similar patterns.

Table G8: Among 2012 treatment households: reasons for cultivating or not cultivating Sahbhagi Dhan again in 2013

Yes: cultivated it again in 2013 143 households 47.8%		**No: did not cultivate it in 2013** 156 households 52.2%	
Why? Choose up to three reasons			
High yield	122	No seeds left due to crop damage	104
Short duration	115	No seeds left due to consumption	65
Good taste/cooking quality	74	Low yield	46
Drought tolerance	68	Unprofitable	44
Profitable	38	Costly inputs needed	19
Seeds are free		Poor taste/cooking quality	13
Low input costs			

Table G9: Among 2014 treatment households: reasons for cultivating or not cultivating Sahbhagi Dhan again in 2014

Yes: plan to cultivate it again in 2014 356 households 62.1%		**No: do not plan to cultivate it in 2014** 217 households 37.9%	
Why? Choose up to three reasons			
High yield	207	No seeds left due to crop damage	104
Short duration	177	No seeds left due to consumption	65
Good taste/cooking quality	177	Low yield	46
Drought tolerance	154	Unprofitable	44
Profitable	118	Costly inputs needed	19
Seeds are free	53	Poor taste/cooking quality	13
Low input costs	40		

References

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

Dar, MH, Singh, S, Singh, US, Zaidi, NW and Ismail, AM, 2014. Stress tolerant rice varieties: making headway in India. *SATSA Mukhapatra – Annual Technical Issue*, 18, pp.1–14.

David, CC and Otsuka, K, 1994. *Modern rice technology and income distribution in Asia*. Boulder, Colorado: Lynne Rienner.

Estudillo, JP and Otsuka, K, 2013. Lessons from the Asian Green Revolution in rice. In: K Otsuka and DF Larson, eds. *An African Green Revolution: finding ways to boost productivity on small farms*. New York: Springer.

Evenson, R and Gollin, D, 2003. Assessing the impact of the green revolution, 1960 to 2000. *Science*, 300, pp.758–762.

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

Food and Agriculture Organization (FAO), 2012. *The State of Food Insecurity in the World 2012*. Rome: FAO.

Hertel, TW, Burke, MB and Lobell, DB, 2010. The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change*, 20, pp.577–585.

Intergovernmental Panel on Climate Change (IPCC), 2014. *Climate Change 2014: Impacts, adaptation, and vulnerability. Summary for policymakers.* Cambridge, UK and New York: Cambridge University Press.

Launio, CC, Redondo, GO, Beltran, JC and Morooka, Y, 2008. Adoption and spatial diversity of later generation modern rice varieties in the Philippines. *Agronomy Journal*, 100(5), pp.1380–1389.

Lobell, B, Schlenker, W and Costa, RJ, 2011. Climate trends and global crop production since 1980. *Science*, 333(6042), pp.616–620.

Malabayabas, AJB, Kajisa, K, Mazid, MA, Palis, FG and Johnson, DE, 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*, 12(4), pp.459–470.

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

Otsuka, K, Estudillo, JP and Sawada, Y eds., 2008*. Rural poverty and income dynamics in Asia and Africa.* Routledge. National Graduate Institute for Policy Studies Global Center of Excellence, Economics Working Paper No. 6, April 2009.

Tubiello, FN, Soussana, J-F, Howden, SM and Easterling, W, 2007. Crop and pasture response to climate change. *Procedures of the National Academy of Sciences USA*, 104, pp.19686–19690.

Wassmann, R, Nelson, GC, Peng, SB, Sumfleth, K, Jagadish, SVK, Hosen, Y and Rosegrant, MW, 2010. Rice and global climate change. In: S Pandey, D Byerlee, D Dawe, A Dobermann, S Mohanty, S Rozelle and B Hardy, eds. *Rice in the global economy: strategic research and policy issues for food security*. Los Baños (Philippines): International Rice Research Institute, pp.411–432.

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

Yamano, T, Panda, A, Ishika, G, Mehar, M and Malabayabas, ML, 2014. *Rice monitoring survey 2014 in India*. In mimeo. International Rice Research Institute. (RMS report submitted to BMGF, 2014)

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

Other publications in the 3ie Impact Evaluation Report Series

The following reports are available from http://www.3ieimpact.org/evidence-hub/impact-evaluation-repository

Poverty and empowerment impacts of the Bihar Rural Livelihoods Project in India, 3ie Impact Evaluation Report 71. Hoffmann, V, Rao, V, Datta, U, Sanyal, P, Surendra, V and Majumdar, S 2018.

How should Tanzania use its natural gas? Citizens' views from a nationwide Deliberative Poll, 3ie Impact Evaluation Report 70. Birdsall, N, Fishkin, J, Haqqi, F, Kinyondo, A, Moyo, M, Richmond, J and Sandefur, J, 2018.

Impact evaluation of the conditional cash transfer program for secondary school attendance in Macedonia, 3ie Impact Evaluation Report 69. Armand, A and Carneiro, P, 2018.

Age at marriage, women's education, and mother and child outcomes in Bangladesh, 3ie Impact Evaluation Report 68. Field, E, Glennerster, R, Nazneen, S, Pimkina, S, Sen, I and Buchmann, N, 2018.

Evaluating agricultural information dissemination in western Kenya, *3ie Impact Evaluation Report 67.* Fabregas, R, Kremer, M, Robinson, J and Schilbach, F, 2017.

General equilibrium impact assessment of the Productive Safety Net Program in Ethiopia, 3ie Impact Evaluation Report 66. Filipski, M, Taylor, JE, Abegaz, GA, Ferede, T, Taffesse, AS and Diao, X, 2017.

Impact of the Uddeepan programme on child health and nutrition in India, 3ie Impact Evaluation Report 65. Kochar, A, Sharma, A and Sharma, A, 2017.

Evaluating oral HIV self-testing to increase HIV testing uptake among truck drivers in Kenya, 3ie Impact Evaluation Report 64. Kelvin, EA, Mwai, E, Romo, ML, George, G, Govender, K, Mantell, JE, Strauss, M, Nyaga, EN and Odhiambo, JO, 2017.

Integration of EPI and paediatric HIV services for improved ART initiation in Zimbabwe, *3ie Impact Evaluation Report 63.* Prescott, M, Boeke, C, Gotora, T, Mafaune, HW, Motsi, W, Graves, J, Mangwiro, A and McCarthy, E, 2017.

Increasing male partner HIV testing using self-test kits in Kenya, 3ie Impact Evaluation Report 62. Gichangi, A, Korte, JE, Wambua, J, Vrana, C and Stevens, D, 2017.

Evaluating the impact of community health worker integration into prevention of mother-to-child transmission of HIV services in Tanzania, 3ie Impact Evaluation Report 61. Nance, N, McCoy, S, Ngilangwa, D, Masanja, J, Njau, P and Noronha, R, 2017.

Using HIV self-testing to promote male partner and couples testing in Kenya, 3ie Impact Evaluation Report 60. Thirumurthy, H, Omanga, E, Obonyo, B, Masters, S and Agot, K, 2017.

Increasing male partner HIV self-testing at antenatal care clinics in Kenya, 3ie Impact Evaluation Report 59. Gichangi, A, Korte, JE, Wambua, J, Vrana, C and Stevens, D, 2017.

Impact of free availability of public childcare on labour supply and child development in Brazil, *3ie Impact Evaluation Report 58*. Attanasio, O, Paes de Barros, R, Carneiro, P, Evans, D, Lima, L, Olinto, P and Schady, N, 2017.

Estimating the effects of a low-cost early stimulation and parenting education programme in Mexico, 3ie Impact Evaluation Report 57. Cardenas, S, Evans, D and Holland, P, 2017.

The Better Obstetrics in Rural Nigeria study: an impact evaluation of the Nigerian Midwives Service Scheme, 3ie Impact Evaluation Report 56. Okeke, E, Glick, P, Abubakar, IS, Chari, AV, Pitchforth, E, Exley, J, Bashir, U, Setodji, C, Gu, K and Onwujekwe, O, 2017.

*The Productive Safety Net Programme in Ethiopia: impacts on children's schooling, labour and nutritional statu*s, *3ie Impact Evaluation Report 55.* Berhane, G, Hoddinott, J, Kumar, N and Margolies, A, 2016.

The impact of youth skills training on the financial behaviour, employability and educational choice in Morocco, 3ie Impact Evaluation Report 54. Bausch, J, Dyer, P, Gardiner, D, Kluve, J and Mizrokhi, E, 2016.

Using advertisements to create demand for voluntary medical male circumcision in South Africa, 3ie Impact Evaluation Report 53. Frade, S, Friedman, W, Rech, D and Wilson, N, 2016.

The use of peer referral incentives to increase demand for voluntary medical male circumcision in Zambia, 3ie Impact Evaluation Report 52. Zanolini, A, Bolton, C, Lyabola, LL, Phiri, G, Samona, A, Kaonga, A and Harsha Thirumurthy, H, 2016.

Using smartphone raffles to increase demand for voluntary medical male circumcision in Tanzania, 3ie Impact Evaluation Report 51. Mahler, H and Bazant, E, 2016.

Voluntary medical male circumcision uptake through soccer in Zimbabwe, 3ie Impact Evaluation Report 50. DeCelles, J, Kaufman, Z, Bhauti, K, Hershow, R, Weiss, H, Chaibva, C, Moyo, N, Braunschweig, E, Mantula, F, Hatzold, K and Ross, D, 2016.

Measuring the impact of SMS-based interventions on uptake of voluntary medical male circumcision in Zambia, 3ie Impact Evaluation Report 49. Leiby, K, Connor, A, Tsague, L, Sapele, C, Koanga, A, Kakaire, J and Wang, P, 2016.

Assessing the impact of delivering messages through intimate partners to create demand for voluntary medical male circumcision in Uganda, 3ie Impact Evaluation Report 48. Semeere, AS, Bbaale, DS, Castelnuovo, B, Kiragga, A, Kigozi, J, Muganzi, A, Kambugu, A and Coutinho, AG, 2016.

Optimising the use of economic interventions to increase demand for voluntary medical male circumcision in Kenya, 3ie Impact Evaluation Report 47. Thirumurthy, H, Omanga, E, Rao, SO, Murray, K, Masters, S and Agot, K, 2016.

The impact of earned and windfall cash transfers on livelihoods and conservation in Sierra Leone, 3ie Impact Evaluation Report 46. Bulte, E, Conteh, B, Kontoleon, A, List, J, Mokuwa, E, Richards, P, Turley, T and Voors, M, 2016.

Property tax experiment in Pakistan: Incentivising tax collection and improving performance, 3ie Impact Evaluation Report 45. Khan, A, Khwaja, A and Olken, B, 2016.

Impact of mobile message reminders on tuberculosis treatment outcomes in Pakistan, 3ie Impact Evaluation Report 44. Mohammed, S, Glennerster, R and Khan, A, 2016.

Making networks work for policy: Evidence from agricultural technology adoption in Malawi, 3ie Impact Evaluation Report 43. Beaman, L, BenYishay, A, Fatch, P, Magruder, J and Mobarak, AM, 2016.

Estimating the impact and cost-effectiveness of expanding access to secondary education in Ghana, 3ie Impact Evaluation Report 42. Dupas, P, Duflo, E and Kremer, M, 2016.

Evaluating the effectiveness of computers as tutors in China, 3ie Impact Evaluation Report 41. Mo, D, Bai, Y, Boswell, M and Rozelle, S, 2016.

Micro entrepreneurship support programme in Chile, 3ie Impact Evaluation Report 40. Martínez, CA, Puentes, EE and Ruiz-Tagle, JV, 2016.

Thirty-five years later: evaluating the impacts of a child health and family planning programme in Bangladesh, 3ie Impact Evaluation Report 39. Barham, T, Kuhn, R, Menken, J and Razzaque, A, 2016.

Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection and malnutrition in India, 3ie Impact Evaluation Report 38. Clasen, T, Boisson, S, Routray, P, Torondel, B, Bell, M, Cumming, O, Ensink, J, Freeman, M and Jenkins, M, 2016.

Evaluating the impact of vocational education vouchers on out-of-school youth in Kenya, 3ie Impact Evaluation Report 37. Hicks, JH, Kremer, M, Mbiti, I and Miguel, E, 2016.

Removing barriers to higher education in Chile: evaluation of peer effects and scholarships for test preparation, 3ie Impact Evaluation Report 36. Banerjee, A, Duflo E and Gallego, F, 2016.

Sustainability of impact: dimensions of decline and persistence in adopting a biofortified crop in Uganda, 3ie Impact Evaluation Report 35. McNiven, S, Gilligan, DO and Hotz, C 2016.

A triple win? The impact of Tanzania's Joint Forest Management programme on livelihoods, governance and forests, *3ie Impact Evaluation Report 34.* Persha, L and Meshack, C, 2016.

The effect of conditional transfers on intimate partner violence: evidence from Northern Ecuador, 3ie Impact Evaluation Report 33. Hidrobo, M, Peterman, A and Heise, L, 2016.

The effect of transfers and preschool on children's cognitive development in Uganda, 3*ie Impact Evaluation Report 32*. Gillian, DO and Roy, S, 2016.

Can egovernance reduce capture of public programmes? Experimental evidence from India's employment guarantee, 3ie Impact Evaluation Report 31. Banerjee, A, Duflo, E, Imbert, C, Mathew, S and Pande, R, 2015.

Improving maternal and child health in India: evaluating demand and supply strategies, 3ie Impact Evaluation Report 30. Mohanan, M, Miller, G, Forgia, GL, Shekhar, S and Singh, K, 2016.

Smallholder access to weather securities in India: demand and impact on production decisions, 3ie Impact Evaluation Report 28. Ceballos, F, Manuel, I, Robles, M and Butler, A, 2015.

What happens once the intervention ends? The medium-term impacts of a cash transfer programme in Malawi, 3ie Impact Evaluation Report 27. Baird, S, Chirwa, E, McIntosh, C and Özler, B, 2015.

Validation of hearing screening procedures in Ecuadorian schools, 3ie Impact Evaluation Report 26. Muñoz, K, White, K, Callow-Heusser, C and Ortiz, E, 2015.

Assessing the impact of farmer field schools on fertilizer use in China, 3ie Impact Evaluation Report 25. Burger, N, Fu, M, Gu, K, Jia, X, Kumar, KB and Mingliang, G, 2015.

The SASA! study: a cluster randomised trial to assess the impact of a violence and HIV prevention programme in Kampala, Uganda, *3ie Impact Evaluation Report 24.* Watts, C, Devries, K, Kiss, L, Abramsky, T, Kyegombe, N and Michau, L, 2014.

Enhancing food production and food security through improved inputs: an evaluation of Tanzania's National Agricultural Input Voucher Scheme with a focus on gender impacts, 3ie Impact Evaluation Report 23. Gine, X, Patel, S, Cuellar-Martinez, C, McCoy, S and Lauren, R, 2015.

A wide angle view of learning: evaluation of the CCE and LEP programmes in Haryana, 3ie Impact Evaluation Report 22. Duflo, E, Berry, J, Mukerji, S and Shotland, M, 2015.

Shelter from the storm: upgrading housing infrastructure in Latin American slums, *3ie Impact Evaluation Report 21.* Galiani, S, Gertler, P, Cooper, R, Martinez, S, Ross, A and Undurraga, R, 2015.

Environmental and socioeconomic impacts of Mexico's payments for ecosystem services programme, *3ie Impact Evaluation Report 20.* Alix-Garcia, J, Aronson, G, Radeloff, V, Ramirez-Reyes, C, Shapiro, E, Sims, K and Yañez-Pagans, P, 2015.

A randomised evaluation of the effects of an agricultural insurance programme on rural households' behaviour: evidence from China, 3ie Impact Evaluation Report 19. Cai, J, de Janvry, A and Sadoulet, E, 2014.

Impact of malaria control and enhanced literacy instruction on educational outcomes among school children in Kenya: a multi-sectoral, prospective, randomised evaluation, 3ie Impact Evaluation Report 18. Brooker, S and Halliday, K, 2015.

Assessing long-term impacts of conditional cash transfers on children and young adults in rural Nicaragua, *3ie Impact Evaluation Report 17.* Barham, T, Macours, K, Maluccio, JA, Regalia, F, Aguilera, V and Moncada, ME, 2014.

The impact of mother literacy and participation programmes on child learning: evidence from a randomised evaluation in India, 3ie Impact Evaluation Report 16. Banerji, R, Berry, J and Shortland, M, 2014.

A youth wage subsidy experiment for South Africa, 3ie Impact Evaluation Report 15. Levinsohn, J, Rankin, N, Roberts, G and Schöer, V, 2014.

Providing collateral and improving product market access for smallholder farmers: a randomised evaluation of inventory credit in Sierra Leone, 3ie Impact Evaluation Report 14. Casaburi, L, Glennerster, R, Suri, T and Kamara, S, 2014.

Scaling up male circumcision service provision: results from a randomised evaluation in Malawi, 3ie Impact Evaluation Report 13. Thornton, R, Chinkhumba, J, Godlonton, S and Pierotti, R, 2014.

Targeting the poor: evidence from a field experiment in Indonesia, 3ie Impact Evaluation Report 12. Atlas, V, Banerjee, A, Hanna, R, Olken, B, Wai-poi, M and Purnamasari, R, 2014.

An impact evaluation of information disclosure on elected representatives' performance: evidence from rural and urban India, 3ie Impact Evaluation Report 11. Banerjee, A, Duflo, E, Imbert, C, Pande, R, Walton, M and Mahapatra, B, 2014.

Truth-telling by third-party audits and the response of polluting firms: Experimental evidence from India, 3ie Impact Evaluation Report 10. Duflo, E, Greenstone, M, Pande, R and Ryan, N, 2013.

No margin, no mission? Evaluating the role of incentives in the distribution of public goods in Zambia, *3ie Impact Evaluation Report 9.* Ashraf, N, Bandiera, O and Jack, K, 2013.

Paying for performance in China's battle against anaemia, *3ie Impact Evaluation Report 8.* Zhang, L, Rozelle, S and Shi, Y, 2013.

Social and economic impacts of Tuungane: final report on the effects of a community-driven reconstruction programme in the Democratic Republic of Congo, *3ie Impact Evaluation Report 7*. Humphreys, M, Sanchez de la Sierra, R and van der Windt, P, 2013.

The impact of daycare on maternal labour supply and child development in Mexico, *3ie Impact Evaluation Report 6*. Angeles, G, Gadsden, P, Galiani, S, Gertler, P, Herrera, A, Kariger, P and Seira, E, 2014.

Impact evaluation of the non-contributory social pension programme 70 y más in Mexico, *3ie Impact Evaluation Report 5*. Rodríguez, A, Espinoza, B, Tamayo, K, Pereda, P, Góngora, V, Tagliaferro, G and Solís, M, 2014.

Does marginal cost pricing of electricity affect groundwater pumping behaviour of farmers? Evidence from India, 3ie Impact Evaluation Report 4. Meenakshi, JV, Banerji, A, Mukherji, A and Gupta, A, 2013.

The GoBifo project evaluation report: Assessing the impacts of community-driven development in Sierra Leone, *3ie Impact Evaluation Report 3*. Casey, K, Glennerster, R and Miguel, E, 2013.

A rapid assessment randomised-controlled trial of improved cookstoves in rural Ghana, *3ie Impact Evaluation Report 2.* Burwen, J and Levine, DI, 2012.

The promise of preschool in Africa: A randomised impact evaluation of early childhood development in rural Mozambique, *3ie Impact Evaluation Report 1.* Martinez, S, Naudeau, S and Pereira, V, 2012.

This evaluation examines the impact of cultivating a new variety of rice, *Sahbhagi Dhan*, to reduce yield losses during droughts for farmers in eastern states of India. This rice variety matures early, avoiding high temperatures that affect yield in traditional rice varieties. However, contrary to findings from agronomic studies, this impact evaluation finds limited evidence that *Sahbhagi Dhan* is drought resistant.

Impact Evaluation Series

International Initiative for Impact Evaluation
202-203, Rectangle One
D-4, Saket District Centre
New Delhi – 110017
India

3ie@3ieimpact.org
Tel: +91 11 4989 4444

www.3ieimpact.org