



Case Report

Drought Tolerant Rice for Ensuring Food Security in Eastern India

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Abstract: Drought and limited availability of water serve as the serious limitation for rice production in rainfed ecosystems. Among the major rainfed rice-cultivating areas, states of eastern India occupy one of the largest drought-prone ecologies in the world. Cultivating drought tolerant rice varieties can serve as the most coherent approach to ensure food security in these areas. International Rice Research Institute (IRRI), along with its national collaborators, has developed drought tolerant rice varieties possessing high yield along with desirable grain quality. One such conventionally bred line, IR74371-70-1-1, has been released with different names in the different countries: in India as Sahbhagi Dhan, in Nepal as Sukha Dhan 3, and in Bangladesh as BRRI Dhan 56. This indicates the suitability of this line to show better performance across the wide range of environments. Sahbhagi Dhan is a short duration variety that has genetic drought tolerance and is more efficient at extracting available moisture from the soil. During drought years, farmers cultivating Sahbhagi Dhan obtained the yield advantage of 0.8 to 1.6 t ha⁻¹ over currently grown long duration as well as traditional varieties. In 2012, when the paddy crop was hit by drought, Sahbhagi Dhan revealed the yield advantage of more than a t ha⁻¹, which reduced to 0.78 and 0.56 t ha⁻¹ during non-drought years of 2013 and 2014, respectively. Data taken from head to head trials during 2017 showed that Sahbhagi Dhan exhibited better performance over the existing rice varieties grown by farmers even under non-drought conditions. The important feature of Sahbhagi Dhan is its evident impact under drought and no yield penalty under favorable conditions over the counterfactual varieties of the same duration. Along with better yield under drought, the important advantage of Sahbhagi Dhan is the short maturity duration of this variety. This allows the farmers to advance the succeeding crop and creates an opportunity for accommodating an additional crop under favorable rainfed ecology, thereby enhancing the cropping intensity. Since the majority of the farmers living in drought prone ecologies are socio-economically under privileged, Sahbhagi Dhan, along with other drought tolerant varieties, can serve as one of the most viable and deliverable technologies for eradicating poverty from these ecologies dependent on rainfed rice.

Keywords: rainfed rice; food security; drought tolerance; Sahbhagi Dhan; IRRI

1. Introduction

Rice serves as the main staple food for more than half of the world's 7 billion people. However, the production of this crop is progressively being limited by several environmental stresses with about 30% of the 700 million poor affected in rainfed lowlands of Asia alone [1]. Drought and limited availability of water serve as the serious constraint for rice production and it has been estimated that more than 50% of the global rice area is affected by drought [2,3]. About 34 million ha of rainfed lowland and 8 million ha of upland rice in Asia is being affected every year from drought stress of varying intensities [4]. Among the various rainfed rice-growing ecologies, India and adjoining areas of Nepal occupy one of the largest drought-prone areas in the world. In India, out of the total 20.4 million ha of rainfed rice, about 16.2 million ha is occupied by eastern Indian states, of which 6.3 million ha of upland and 7.3 million ha of lowland areas are drought-prone [4,5]. Severe droughts witnessed in India during 2002, 2003, 2009 and 2010 caused significant reduction in rice yields particularly in eastern Indian states of Jharkhand, Bihar, Uttar Pradesh, Chhattisgarh, and Odisha. Similarly, the severe drought in parts of eastern Uttar Pradesh and Bihar devastated rice crop during 2015.

Rice grain yield, as well as vegetative growth, is severely reduced under drought stress [6,7]. Reduction in grain size, grain weight, and seed-setting rate are commonly observed under the scarce water conditions [8,9]. Drought stress during booting, flowering, and terminal stages can interrupt floret initiation, cause spikelet sterility, resulting in lower grain weight and ultimately leading to poor grain yield [10,11]. The reduction in yield may also be due to water scarcity induced decrease in CO₂ assimilation rates, low stomatal conductance, declined level of photosynthetic pigments, smaller leaf area, reduced stem extensions, reduction in water use efficiency, repressed activities of starch synthesising enzymes, and inappropriate partitioning of assimilates [12]. The extent of grain yield losses depends on the duration of water scarcity, the crop growth stage, and the intensity of the stress [9,13].

Due to the continuing adverse effects of climate change, water deficit is expected to be a major challenge for sustained rice production in the near future [14]. The speculations regarding increase in frequency and intensity of droughts lays serious threat to sustained rice production and therefore to global food security [15]. A significant proportion of the drought-prone areas are also prone to submergence. The late duration cultivars grown in rainfed areas usually come across with submergence at seedling stage and with drought during flowering, giving rise to huge yield losses [1]. Severe droughts also had far-reaching impacts on the production and productivity of succeeding season crops. Farmers cultivating rice in drought prone ecologies are well aware about the risks associated and are thus disinclined towards using costly agricultural inputs, thereby leading to further reduction in yield potential [16]. Moreover, the majority of the farmers living in drought prone areas belong to socio-economically weaker sections of the society. Thus, drought affects the under privileged farmers disproportionately, leading them to reduce their consumption, withdraw their children from schools, impose them to migrate for employment, and sell assets to meet immediate needs [17].

The varieties exhibiting drought tolerance along with better grain yield and desirable quality can serve as the most logical approach to cope up with the menaces inflicted by drought [18]. Although rapid advancements have been made in developing drought tolerant rice varieties, continuous attempts need to be carried out to disseminate these varieties in unfavourable growing environments. These varieties can serve as the most viable and deliverable technologies for eradicating poverty from the ecologies dependent on rainfed rice [19].

2. Drought Tolerant Rice Varieties

Although the requirement of drought tolerant cultivars has been felt since long to ensure rice production in rainfed areas, little efforts have been devoted for developing such cultivars in the past. The main reason is that identifying rice genotypes possessing higher degrees of drought tolerance for use as donors in breeding programs is one of the key challenges for rice research [20]. Due to the intricate nature of drought and complications in bringing several drought-tolerance features

together along with high yield potential under non-drought conditions, the progress in breeding for drought tolerance has been very slow [21]. Research on development of drought tolerant varieties of rice was initiated by International Rice Research Institute (IRRI) in the 1960s, but it was only about a decade back when promising results emerged. Some drought tolerant genotypes (like IR 74371-46-1-1, IR 74371-54-1-1, and IR 74371-70-1-1) developed by IRRI through conventional breeding, showed excellent results in India, Bangladesh, and Nepal. Under severe droughts, where most of these high yielding varieties got completely vanished, the drought tolerant lines yielded around 0.8–1.0 t ha⁻¹. Even under normal conditions, these drought tolerant lines outperformed the currently grown popular rice varieties in drought prone areas [8,21]. Similarly, the three IR64 QTL lines (IR 87707-445-B-B, IR 87707-446-B-B, and IR 87707-182-B-B) were developed that out yielded IR64 by 0.5 to 1.8 t ha⁻¹ under different severities of drought [22]. Likewise, the varieties like CR Dhan, Sushk Samrat, and Abhishek have also been capable of stabilizing rice production in the rainfed lowlands of eastern India [1]. Moreover, different drought tolerant lines have been released in different regions of South Asia (for example, DRR 42, 44 in India, Sukha Dhan 4, 5 in Nepal, and BRRI Dhan 66, 71 in Bangladesh). A conventionally bred line IR74371-70-1-1 has been released with different names in the different countries: in India as Sahbhagi Dhan, in Nepal as Sukha Dhan 3, and in Bangladesh as BRRI Dhan 56. This indicates the suitability of this line to show better performance across the wide range of environments. Sahbhagi Dhan exhibits better performance over the existing rice varieties grown by farmers even under non-drought conditions. The important feature of Sahbhagi Dhan is its evident impact under drought and no yield penalty under favourable conditions. This variety is being disseminated to farmers in the areas of eastern India, where droughts are prevalent.

3. Performance of Sahbhagi Dhan

3.1. In Research Trials

The line IR74371-70-1-1 revealed consistently better results under rainfed direct seeded upland and transplanted lowland environments in India, Bangladesh, and Nepal. In India, it was released and notified as Sahbhagi Dhan (SD) in 2010 by the Central Rainfed Upland Rice Research Station, Hazaribagh. Sahbhagi Dhan was projected to be fit for cultivation in Odisha, Jharkhand, and Chhattisgarh, and for transplanted conditions in Tamil Nadu [23]. The variety showed consistently better performance over national, regional, and local checks in national coordinated trials during the wet seasons of 2005–2007. In advanced yield trials at eight institutes in India, grain yields of Sahbhagi Dhan was perpetually higher than the commercial checks under irrigated, moderate drought and severe drought ecologies [24]. Sahbhagi Dhan was found to be most stable yielding among the 40 entries evaluated across 16 rainfed and irrigated ecologies during the wet season trials in eastern India [25]. For multiple drought-tolerance indices, Sahbhagi Dhan was reported to show a very high ranking [8].

Most of the previous studies regarding Sahbhagi Dhan were conducted in research trials and that too on a very limited scale. The thorough evaluation of this variety in farmers' fields is missing. This paper reveals the performance of Sahbhagi Dhan in farmers' field at different locations of eastern India. Its adoption, impact, dissemination, awareness creation, role of women farmers, and development of strategic public–private partnership has been discussed in various sections of this manuscript. The success stories of some farmers along with their testimonials have also been documented.

3.2. In Farmers' Fields

Results of participatory selection trials in farmers' field revealed that Sahbhagi Dhan was liked and preferred by farmers. Testimonials by many farmers have implied about the number of advantages of growing Sahbhagi Dhan over other varieties. Along with better yield under drought, the important benefit as reported by farmers is the short maturity period of this variety. This allows the farmers

to advance the succeeding crop and creates an opportunity for accommodating an extra crop under favourable rainfed ecology, thereby enhancing the cropping intensity. Some previous reports suggest that the stabilization of rice–wheat cropping system due to the decrease in maturity duration of rice is the main factor for enhancing cropping intensity in Indo-Gangetic plains [26,27].

During its first appraisal at farmers' fields in 2010 in eastern Uttar Pradesh (UP), the seeds of Sahabagi Dhan were provided to some farmers through NGOs like Grameen Development Services (GDS) and Gorakhpur Environmental Action Group (GEAG). A female farmer (Meera Devi) from Mohanjyoth village of Maharajgunj harvested 4.5 t ha⁻¹ from Sahbhangi Dhan. Her fellow farmer, Prabhavati, harvested 5 t ha⁻¹, a t ha⁻¹ higher than her previously cultivated variety (NDR 97). Both women reported the better grain and cooking quality of Sahbhangi Dhan over NDR 97, a popular short duration variety in the area. Narvadeshwar Giri, a progressive farmer from Aphaur Village in Nalanda Bihar, affirmed that he obtained an average yield of 4 t ha⁻¹ from Sahbhangi Dhan in 110 days and 4.5 t ha⁻¹ from another variety in 140 days. However, no irrigation was provided to the field cultivated with Sahbhangi Dhan, which resulted in substantial amount of savings in terms of money (each irrigation costs about 1700 rupees ha⁻¹). He reported about 30% of the savings in production cost of Sahbhangi Dhan compared to other varieties. Moreover, due to the early maturing nature of Sahbhangi Dhan, he obtained a mid-crop of fenugreek before wheat, which bestowed him with additional income. The observations by previous researchers have revealed that the drought tolerant rice varieties have the potential to sustain yields, save water, and significantly reduce the cost of cultivation [9,28,29]. Reduction in production cost coupled with increased productivity will enhance the total returns of farmers.

As soon as the seed of Sahabagi Dhan was multiplied in bulk, it was distributed to the states of eastern India through different channels, including thousands of minikits allocated by National Food Security Mission (NFSM). Various activities related to its promotion took place across the states, which encouraged NICRA (National Initiative on Climate Resilient Agriculture) project to distribute Sahbhangi Dhan seed among farmers during the wet season of 2011. Large-scale demonstrations of Sahbhangi Dhan were also carried out in different states under the mega schemes like National Food Security Mission (NFSM) and Bringing Green Revolution to Eastern India (BGREI). STRASA (Salt Tolerant Rice for Africa and South Asia) project along with the assistance from Government of India, distributed the seeds of Sahbhangi Dhan in drought-prone areas of UP, Bihar, West Bengal, Jharkhand, Chhatisgarh, and Odisha. Farmers from all these regions have overwhelmingly expressed their positive response about this variety. In Mayurbhunj (Odisha), where tribal farmers cultivate traditional varieties and usually face heavy losses due to the shortage of water, cultivating Sahbhangi Dhan in 2012 has enabled them to harvest about double their usual yields.

The performance of Sahbhangi Dhan under drought and non-drought environments has been very impressive, which not only promoted the farmers to adopt this variety but also encouraged the seed producers to come forward. The excellent performance of Sahbhangi Dhan at farmers' field is evident from the cluster demonstrations of International Rice Research Institute—National Food Security Mission (IRRI-NFSM) project in eastern Indian states during 2012 to 2014. The farmers harvested excellent crop, yielding significantly higher than the other varieties (Table 1). Sahbhangi Dhan expressed a varying yield advantage over other varieties across the years depending up on the intensity of drought. In 2012, when the paddy crop was hit by drought, Sahbhangi Dhan revealed the yield advantage of more than a t ha⁻¹, which reduced to 0.78 and 0.56 t ha⁻¹ during non-drought years of 2013 and 2014, respectively. The distinctive feature of Sahbhangi Dhan is its evident impact under drought and no yield penalty under favourable ecologies over the counterfactual varieties. Due to the high demand of this variety, the Central Rainfed Upland Rice Research Station in Hazaribagh, obtained a record indent for the breeder seed production of 19 tons under the Department of Agriculture and Cooperation, Ministry of Agriculture during 2014–2015. The seed is sufficient to produce about 50,000 tons of certified seed in the ensuing two years [30].

Table 1. State-wise productivity of Sahbhagi Dhan over other varieties under International Rice Research Institute – National Food Security Mission (IRRI-NFSM) project demonstrations during 2012-14.

States	Yield during 2012 (t ha ⁻¹)			Yield during 2013 (t ha ⁻¹)			Yield during 2014 (t ha ⁻¹)		
	Sahbhagi Dhan	Adjacent Varieties	Advantage	Sahbhagi Dhan	Adjacent Varieties	Advantage	Sahbhagi Dhan	Adjacent Varieties	Advantage
Uttar Pradesh	4.50	3.70	0.80 *	4.10	3.70	0.40 *	3.70	3.40	0.30 *
Bihar	4.50	3.22	1.28 *	4.70	4.40	0.30	4.30	4.00	0.30
Jharkhand	3.70	2.50	1.20 *	3.80	2.70	1.10 *	3.80	3.30	0.50 *
West Bengal	4.47	2.86	1.61 *	4.00	3.20	0.80 *	4.50	3.50	1.00 *
Odisha	3.57	2.56	1.01 *	3.00	2.30	0.70 *	3.50	2.80	0.70 *
Chhattisgarh	-	-	-	4.10	2.70	1.40 *	4.00	3.40	0.60 *
Mean	4.14	2.96	1.18 *	3.95	3.16	0.78 *	3.96	3.40	0.56 *

* indicates that the value is significant at $p = 0.05$.

During the wet season of 2015, eastern Uttar Pradesh faced a severe drought and farmers incurred huge crop losses due to scanty rainfall. Most of the popular rice varieties like Damini, Moti, Sarju 52, and Swarna were severely affected, resulting in very poor or no yields. Sahbhagi Dhan on the other hand was the only variety to yield substantially. The average yield of Sahbhagi Dhan as recorded from various districts of Uttar Pradesh was 3.9 t ha^{-1} , while the yield of other varieties was only 2.9 t ha^{-1} (Table 2). The performance of Sahbhagi Dhan was found to be exceptionally outstanding in district Mau, where most of the local and popular varieties were badly affected by severe drought at tillering and flowering stages. Paddy crop faced complete water deficit for the period of 15–20 days at active tillering (AT) with a short shower just sufficient to saturate the soil surface at panicle initiation (PI). The varieties like Moti and Damini nearly failed to flower, producing less or no yields, while Sahbhagi Dhan yielded between 2.1 to 3.1 t ha^{-1} . Sahbhagi Dhan on an average yielded 2.8 t ha^{-1} with 2–3 life saving irrigations, whereas the average yield of adjacent varieties was 1.1 t ha^{-1} with the same number of irrigations (Figures 1 and 2).



Figure 1. Performance of Sahbhagi Dhan (left in both the photographs) and other varieties in farmers' field at Mau, Uttar Pradesh. (a) Head to head comparison of Sahbhagi Dhan with Moti (a local rice variety); (b) Head to head comparison of Sahbhagi Dhan with Damini (a local rice variety)

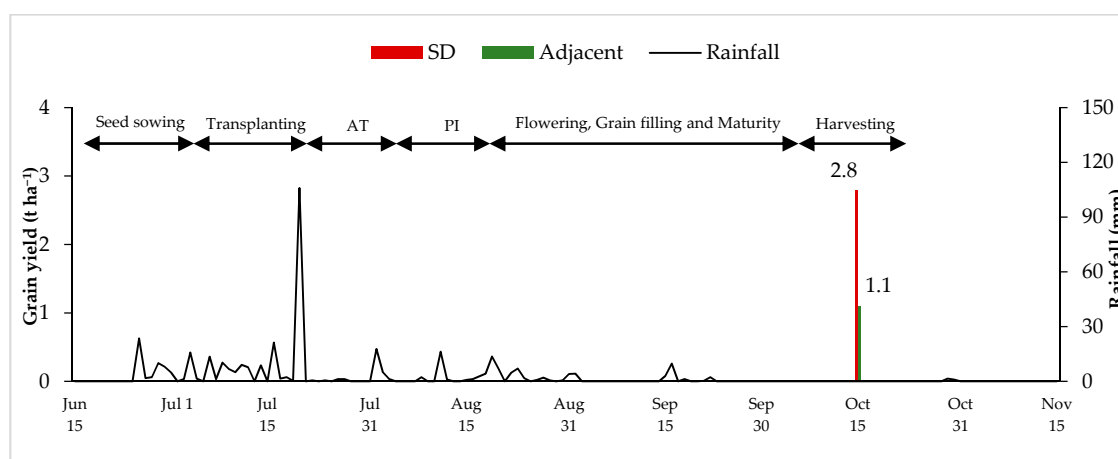


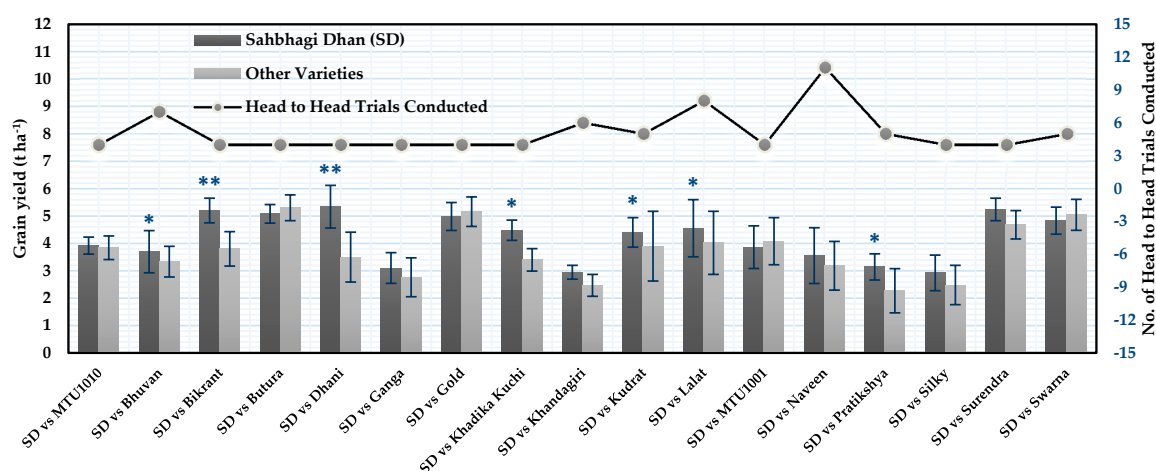
Figure 2. Yield performance of Sahbhagi Dhan (SD) and other varieties under drought during the wet season of 2015 at district Mau (Uttar Pradesh).

Table 2. Yield performance of Sahbhagi Dhan and other varieties during the wet season of 2015 in various districts of Uttar Pradesh.

District	Yield of Sahbhagi Dhan (t ha ⁻¹)	Yield of Adjacent Varieties (t ha ⁻¹)
Mau	2.80 *	1.10
Ghazipur	4.30 *	3.30
Gorakhpur	4.10 *	3.00
Basti	4.30 *	3.60
Azamgarh	4.10 *	3.50
Pratapgarh	4.20 *	2.80
Balrampur	3.90 *	2.70
Allahabad	4.00 *	2.40
Kausambi	4.00 *	3.40
Sultanpur	4.30 *	3.90
Raebareli	4.50 *	4.00
Amethi	2.80 *	2.10
Mean	3.90 *	2.9

* indicates that the value is significantly higher ($p = 0.05$) than the adjacent variety.

During the non-drought year of 2017, the crop cut data was recorded from head to head trials laid by IRRI in farmers' fields under rainfed upland conditions in 15 districts of Odisha. In head to head trials, the pair of varieties to be compared are cultivated in the same field or in two adjacent fields with similar conditions. It was observed that Sahbhagi Dhan showed better performance over the popular rice varieties grown by farmers even under non-drought conditions. The performance of Sahbhagi Dhan was either better or similar to the existing varieties under cultivation (Figure 3).

**Figure 3.** Yield performance of Sahbhagi Dhan (SD) and other varieties in head to head trials laid by International Rice Research Institute (IRRI) in Odisha during the wet season of 2017. The yield data was recorded by crop cutting method from 10 m × 10 m areas; * and ** indicate that the yield of Sahbhagi Dhan is significantly higher than the adjacent variety at the levels $p = 0.05$ and 0.01 , respectively.

In addition to yield advantage, Sahbhagi Dhan also decreased the input cost by demanding a smaller number of irrigations. Moreover, Sahbhagi Dhan being a short duration variety has the potential to enable the farmers to advance the succeeding crop. Thus, creating an opportunity to accommodate the extra crop under favourable rainfed ecology, thereby enhancing the cropping intensity. The rice cultivars with drought tolerance at different growth stages will help farmers to maintain consistent yields over progressively erratic climatic conditions, utilizing lesser resources [9,31,32].

4. Adoption of Sahbhagi Dhan

To track the adoption of Sahbhagi Dhan, a study was conducted in the villages where demonstrations have been carried out in the preceding wet season. Seeds were provided to 17,400 farmers in 28 drought prone districts, in four eastern Indian states, during the wet season of 2013 (Table 3). A random survey was conducted with 10% of the recipient farmers (1740) in October 2014. The highest readoption was found to be 72% in Chhattisgarh, followed by 64% in West Bengal, 60% in Odisha and 50% in Jharkhand. The reasons for not being persistent with Sahbhagi Dhan during the succeeding years were also explored. Interestingly, in Odisha, 71% of the farmers who did not continue with Sahbhagi Dhan lost their crop due to Phailin cyclone. Similarly, in the states of West Bengal, Jharkhand and Chhattisgarh, a substantial number of farmers reported seed losses due to Phailin. The other factors, which resulted into the discontinuation of this variety, include the non-availability of seeds in the market and unawareness about re-using the seed by confusing Sahbhagi Dhan with hybrids. This has taken place mainly in the areas where hybrids are widely cultivated by farmers and extensively promoted by private seed companies.

Table 3. State-wise distribution of Sahbhagi Dhan in eastern India during the year 2013 and its adoption in 2014.

State	No. of Districts	No. of Farmers	Adoption of Sahbhagi Dhan (%)
Odisha	12	6950	60
West Bengal	2	1800	64
Jharkhand	10	7000	50
Chhattisgarh	4	1659	72

An attempt was made to know the factors determining the adoption of Sahbhagi Dhan. Drought tolerance and good grain yield are the major determinants found to drive its adoption across the states. The outcomes of our survey with the reasons for adoption are mentioned in Table 4. The criteria for adoption vary over agro-climatic conditions. Farmers' perception and understanding about various features of the technology also plays an important role in its adoption. Previously conducted studies have revealed that education, size of land holding, access to seed, extension services, yield potential, and consumer preferences play an important role in varietal adoption [33–36]. Farmers examine new cultivars meticulously and make decisions based on relative strength and weakness of the varieties, keeping in view the already existing ones [37].

Table 4. Main characteristics influencing the adoption of Sahbhagi Dhan.

Characteristics	Farmers' Response (%)			
	Odisha	WB	Jharkhand	Chhattisgarh
Drought tolerance, high yield, short duration and good taste	96.99	72.88	95.24	82.02
Good milling recovery, good straw quality, less fertilizer, very less disease and pest and easy threshing	3.01	27.12	4.76	17.98

5. Impacts of Sahbhagi Dhan

5.1. Enhancing Grain Yield under Drought

The main impact of Sahbhagi Dhan rice variety is an average increase in grain yield, especially under drought. During drought years, farmers cultivating Sahbhagi Dhan obtained the yield advantage of 0.8 to 1.6 t ha^{−1} over currently grown long duration as well as traditional varieties. Our survey-based evidence suggests that Sahbhagi Dhan has drought tolerance at multiple growth stages.

5.2. Enhancing Cropping Intensity

Many farmers also reported that early maturing nature of Sahbhagi Dhan enabled them to increase the cropping intensity by expeditious planting of the succeeding crop, thereby adjusting an additional short duration crop in the existing cropping system. Moreover, under the existing cropping system, it is fairly common that men take over other employment after the harvesting season and temporarily migrate to urban areas to earn the better means of livelihood. Cultivating Sahbhagi Dhan has the potential to change this system as men can stay at home to plant an extra crop between the summer and winter seasons.

5.3. Fetching Good Market of the Early Produce

Short maturity duration of Sahbhagi Dhan ensures early access to food. Fetching good market of the early produce has been reported by various farmers. In addition to the low supply of rice in local markets during September to November, there is often a shortage of animal feed in these months. Interviews, surveys and target group discussions revealed that Sahbhagi Dhan provides fodder for animals before the main rice harvest, thereby benefitting the livestock. Additional gains have been accomplished due to the better yield and quality of Sahbhagi Dhan straw.

5.4. Enhancing Yield of the Succeeding Crop

The enhanced grain yield of the succeeding crop has been reported by farmers due to the relatively higher availability of residual moisture after paddy harvesting. Due to the shorter duration of Sahbhagi Dhan, the farmers are able to utilize the residual soil moisture in the fields to grow the succeeding summer season legume or pulse crop. This not only provides extra earnings but also improved nutritional security to the resource poor farmers.

5.5. Enhancing the Working Duration of Resource Poor Farmers

Most of the resource poor farmers leave their fields fallow after rice and migrate for employment as laborers to other locations. The early harvesting of Sahbhagi Dhan can enhance the number of working days and therefore the farmers can earn more to support their families.

5.6. Reducing Input Costs

In surveys and interviews, farmers reported that Sahbhagi Dhan could reduce input costs, especially those invested on irrigation.

5.7. Alleviating the Labor Shortage

Due to the short maturity duration of Sahbhagi Dhan, the timing of various labor operations does not coincide with the same activities for other varieties. This helps to alleviate the labor shortage especially during the crop harvesting months of October and November.

5.8. Enhancing the Flexibility in Planting Time

Cultivating Sahbhagi Dhan also enhances the farmers' flexibility in the choice of planting time, because its short duration nature allows to delay the planting while harvesting can be carried out still on time. Flexibility in planting time is especially important in case of early drought because farmers can wait for the rains to arrive.

5.9. Flexibility in Crop Seed Establishment Methods

Due to the good adaptability of Sahbhagi Dhan, crop management recommendations allow for various seed establishment procedures (direct-seeded or transplanted), based on the occurrence of timely or untimely rains.

5.10. Better Grain Quality

Most of the farmers surveyed have reported about the relatively better grain quality features of Sahbhagi Dhan. The better grain quality ensures good remuneration of the produce.

5.11. Pest and Disease Resistance

Resistance of Sahbhagi Dhan against various pests and diseases like leaf folders, whorl maggots, brown plant hoppers, white backed plant hoppers, gall midge, hispa, thrips, leaf blast, and rice tungro virus has been reported by farmers.

5.12. Qualitative Impact

Besides increase in yield and cropping intensity, and reduction in input as well as labor costs associated with the adoption of Sahbhagi Dhan, there are several other effects that can be evaluated qualitatively but have no quantitative indication. This infers the bearing on behavioral responses to risk management, household practices and investment.

6. Large-Scale Dissemination of Sahbhagi Dhan

The rapid success of Sahbhagi Dhan has attained extensive support from national and international agencies. International Rice Research Institute through STRASA project has been involved in creating intentional and strategic partnerships for transferring the technology to farmers. This project has played a significant role to get strong support from national system for promotion, varietal release and policy issues. STRASA has ensured the development of widespread network of collaborators from both public and private sectors, besides involving non-government and farmers' organizations for awareness creation, seed multiplication and dissemination of Sahbhagi Dhan. The variety is now diffusing at an unprecedented manner in eastern India. This is largely due to its better performance in farmers' field under drought and without any yield penalty under non-drought conditions. Sahbhagi Dhan is expected to have reached more than 300,000 farmers by the wet season of 2017.

A strong network of partners possessing linkages with various national initiatives backing awareness creation, production, and dissemination of quality seeds have been established in eastern India. Within the extensive network, the production and ensuring availability of breeder seed (BS) is being carried out by national research organizations under the supervision of plant breeders. Foundation seed (FS) is being produced by research institutes, agriculture extension departments (federal and state), seed corporations and private seed companies. Certified seed (CS) production is being carried out by the same organizations, and also by trained individual or group of farmers. Coordination of efforts among the activities supported by national and regional governments has also been very effective for multiplication and dissemination of the seed. Linkages with public sector programs and other partners has proved to be very successful for aware generation and out-scaling of the stress tolerant varieties in India.

7. Efforts Taken to Generate Awareness for Drought Tolerant Varieties

Increasing awareness about the worth of newly developed cultivars is one of the most vital steps for their rapid and large-scale adoption. Proper awareness ensures the creation of adequate and continuous demand for quality seed, and catalyzes seed multiplication and marketing by different stakeholders. Rather than emphasizing on large scale cultivation in a few locations, our strategy is to inoculate the larger number of sites with a small quantity of seed of new varieties primarily through lead farmers. New locations for inoculation are chosen during subsequent years, while encouraging the farmer-to-farmer dissemination at the sites covered in the preceding seasons. Every season, new farmers provided with seeds are convinced to sell their produce as seeds to other farmers in the same or neighboring village. This approach was found to be very effective in eastern India. Farmer-to-farmer seed distribution was found to be an effective approach for both pre- and post-release

dissemination [38]. The relative superiority of cultivars in farmers' fields may lead to their quick adoption, because the majority of the farmers get seeds from neighbors and relatives, and improved cultivars spread quickly through exchange once farmers are convinced about their performance [36]. Extensive efforts have been devoted to track the spread of Sahbhagi Dhan. This helps to determine the level to which the variety is spreading amongst the farmers, the locations where seed spreading and adoption rate is slow, and the places where these varieties are more probable to be adopted.

Our results revealed that most of the farmers that did not persist with Sahbhagi Dhan in 2014 did not have any seeds left over from the 2013 produce. Our survey-based evidence suggests that the farmers befuddled the seeds of newly introduced varieties with hybrids. This has acted as a non-trivial barrier for adoption. This clearly indicates that farmers need to be made aware about the importance of preserving seeds for the next cropping season. Moreover, farmers were asked about their perceptions regarding Sahbhagi Dhan and how these got changed over time. About 83% of the farmers reported that they were initially hesitant to plant Sahbhagi Dhan, but their opinion changed for the better over years. Farmers were also asked about the best and worst performing variety under normal and drought years. It appears that farmers perceive Sahbhagi Dhan favorably under both drought and normal conditions. Approximately 17% of the farmers opined for Sahbhagi Dhan as their best performing variety during non-drought years. However, 53% farmers were in favor of hybrids. About 33% of the farmers (highest score) reported Sahbhagi Dhan as their best performing variety under drought. Nevertheless 26% voted for hybrids as their best performing varieties under drought. Not a single farmer cited Sahbhagi Dhan as their worst performing variety either under normal or drought conditions. Overall results suggested that this variety has transcendence over other short duration varieties (like, Lalat, IR64, and IR36) and hybrids in stabilizing rice yields under drought conditions. STRASA has been closely working with local partners to ensure the faster dissemination of Sahbhagi Dhan and other drought tolerant varieties.

8. Head to Head Trials as a New Model of Extension

The commonly used method of agricultural extension is to setup large scale cluster demonstrations where selected farmers grow the improved variety and other farmers in the vicinity are invited to come and see the results. Demonstration plots display a treatment, but not a related counterfactual. As a result, they do not assist farmers learn-by-comparing the new variety in view of their existing technology. They can observe outcome, but they cannot appraise the gain. Appraising gain entails setting up of a control plot planted with the next best alternate available to the farmer under the same farmer-determined farming practices. Besides, demonstration plots do not appreciate relevance for social learning in not detailing the conditions under which the yield has been realized. So, the visiting farmers are not able to equate these conditions to their own circumstances. To overcome the limitations of field demonstrations, STRASA project has started a campaign for conducting head to head trials in the farmers' fields. In these trials, the pair of varieties to be compared are grown in the same field (half of the field for each variety) or in two adjacent fields with similar conditions. These trials allow the farmers to assess the genetic potential of new variety under normal conditions, while comparing it with the already existing one. These also improve farmers' learning in their self-managed plots. Hundreds of such trials for Sahbhagi Dhan are being conducted at farmers' fields and revealing promising results against the counterfactuals. This has boosted the confidence of farmers regarding drought tolerant varieties. The data from various head to head trials reveal the substantial yield advantage of Sahbhagi Dhan over other varieties under normal conditions. This has helped to enhance the adoption of this variety amongst farmers.

9. Role of Women Farmers in Varietal Dissemination

Paddy cultivation is the major source of livelihood for most of the rural women in eastern India. In most of the stress prone areas with inadequate extension services, women have been taking the forefront in all rice farming-related activities [39]. Instead of being mere beneficiaries, female farmers act

as experts and possess cognition that can complement the formal knowledge of agricultural experts [40]. Therefore, women farmers can act as the best agents for disseminating the information and seeds of stress tolerant rice varieties (STRVs). Keeping in view the importance of women farmers for promotion and dissemination of STRVs, STRASA have rolled out initiatives to ensure farm productivity and food security through female farmer groups. STRASA has come up with the approaches that promote female farmers as the primary mediators of change in their communities. The main objective is to reach all farmers of the village by deploying members of existing female farmer groups in that area. This approach is based on the hypothesis that the female farmers facilitate the spread of information and seed of STRVs in their social networks, thereby generating sustainable processes and practices [41,42]. If one member of the group adopts a technology successfully, other members learn and share the innovation, thus developing multiplier effects. STRASA renders the capacity building of such groups, thereby strengthening their potential, improving their decision making and enabling them to provide correct feedback to researchers.

In Eastern India, where female farmers are ranked high in vulnerability mapping [43], the mass introduction of STRVs through women groups can prove to be a potential game changer in the socio-economic and food production dynamics of the region. Sahbhagi dhan was also disseminated through the NGOs specifically working with women self-help groups (SHGs) and other female farmers. We have focused on working with the groups that had a local established base for improving the livelihoods and empowering the women through different interventions. One such organisation is Rajiv Gandhi Mahila Vikas Pariyojana (RGMVP) which organizes poor rural women into community organizations in the form of self-help groups (SHGs), each group having ten to twenty women. RGMVP has framed an economical, sustainable, and scalable poverty reduction and women empowerment model. This model has been exploited for the dissemination of information and seeds of drought tolerant varieties.

10. Strategic Public–Private Partnership for the Dissemination of Drought Tolerant Rice

STRASA facilitated the programs where formal seed sector (public and private) and extension systems participated in the multiplication and upscaling of STRVs. Formal seed system and farmer seed system have complementary roles to play in promoting the agricultural development. STRASA is strengthening both the systems to accelerate the promotion and acceptability of new varieties in pipeline. The project has developed a promotional roadmap by connecting public, private and state seed establishments with the institutions that produce breeder seeds. This permits the newly developed cultivars to go into the formal seed chain as early as the first year of their release. For example, the Seed Association of Bengal, an assembly of more than 45 seed companies supplying seeds to many states of eastern India, has taken up the large scale seed production of Sahbhagi Dhan. The seed production of DRR42, a newly released drought tolerant rice variety, has also been taken up by these private companies in the very first year of its release. The partnerships are acquiring impetus in the seed sector, thus allowing the fast-track commercialization of STRVs. This allows the large-scale distribution of seeds to ensure the benefit for large number of farmers. STRASA supports the small seed companies by awareness creation about STRVs and conducting small demonstrations through the dealers' network. Drought tolerant rice varieties represent the topmost priority of the breeder seed indent from various agencies, submitted to the Department of Agriculture and Cooperation, Ministry of Agriculture.

11. Success Stories of Some Farmers

Farmers have been appraising Sahbhagi Dhan since the development of this variety. The feedback from farmers is important for breeders and agronomists for the further improvement of existing varieties, for the development of new breeding genotypes, and for recommending the best management practices. Some of the farmers' testimonials on how the drought tolerant variety Sahbhagi Dhan has affected their livelihoods has been given in Table 5.

Table 5. Some of the farmers' testimonials on how the Sahbhagi Dhan has changed their livelihood.

Farmer and Site	Cases of Success
Mrs. Jeema Purty, Hadaguttu, Mayurbhanj, Odisha, India	<p>This marginal women farmer has been living in dejected poverty since the untimely demise of her husband. With four kids, she had to fight against all odds and troubles. She used to work in her neighbors' farm as a daily laborer for the survival of her children. The locally available paddy that she used to grow in the small piece of land inherited from her husband's family could yield only below minimum of their requirement, mainly due to unavailability of monsoons. She had been looking for a rice variety that requires less water and can tolerate drought. Finally, she comes across an active animator of Holy Family Parish at Lavnayadeipur who encouraged her to try a new drought tolerant short duration Sahbhagi Dhan variety. She received 20 Kg of Sahbhagi Dhan seed from the Church in 2012 and planted it in her field. The excellent yield performance of Sahbhagi Dhan enticed her and just after paddy harvesting, she again invested on land with seasonal vegetables. This was the beginning of her changed life. "I am a farmer now and I need not to work in others' farm for survival. I have choices and varieties at my childrens' plate", beaming Jeema affirms. Jeema is now a new entrant to the market as seller. She is known with the title of business woman among her peers. She is also an active member of a village level SHG and VAT (Village Action Team).</p>
Mr. Ukeel Mahato, Rangamatia, Purulia, West Bengal, India	<p>This is a small land holding farmer who supports his family through rice crop cultivation. Like other farmers, he harvests only one crop per year as frequent droughts being regular feature of the area. Farmers in this area had been cultivating traditional varieties since long and obtaining grain yield of only 1–2 t ha⁻¹. Introducing Sahbhagi Dhan under IRRI-NFSM programme during 2012 has changed the scenario of farmers. Mr. Mahato has cultivated Sahbhagi Dhan on 0.6 ha of land and obtained almost double the yield (4.2 t ha⁻¹) compared to local varieties (2.2 t ha⁻¹). "Sahbhagi Dhan reveals more tolerance to drought than other varieties", says Mahato. He also distributed the seed of Sahbhagi Dhan among many farmers of his village.</p>
Mr. Dileep Oraon, Kita, Latehar, Jharkhand, India	<p>The marginal farmer belongs to tribal community and depends exclusively on wet season rice from 1.2 ha of his land. He cultivates only one crop due to the lack of irrigation, scanty rainfall and drought prone conditions. He received seeds of Sahbhagi Dhan as a part of IRRI-NFSM demonstration through Samas Vikas Sanstha in 2012 and cultivated it on 0.4 ha of land. Severe droughts for 15–18 days incurred at tillering and flowering stages which affected the yield of other varieties like Hazari Dhan and Naveen. However, the Sahbhagi Dhan was left unimpaired. "The yield of Sahbhagi Dhan was 4.2 t ha⁻¹, whereas Hazari Dhan and Naveen in adjacent plots yielded 2.5 t ha⁻¹ and 2.9 t ha⁻¹, respectively", says Dileep. He also reported that drought inducts more numbers of unfilled grains in Naveen and Hazari Dhan than in Sahbhagi Dhan. Mr. Dileep is extremely satisfied with Sahbhagi Dhan and has also distributed its seeds among his fellow farmers.</p>
Mrs. Prabhawati Devi, Karaundi Narayanpur, Mau, Uttar Pradesh, India	<p>This marginal women farmer lives with her husband along with two sons and four daughters. To support her family, Prabhawati practices share-cropping on 0.8 ha of land, in addition to cultivating her own land of 0.3 ha. Her husband works in a brick kiln as laborer. She has no irrigation facility and frequent droughts from last 3–4 years have kept her worried regarding the rice production. Moreover, she has been associated with Rajeev Gandhi Mahila Vikas Pariyojana (RGMVP) since last 3 years and is a member of SHG, Shankar Mahila Gram Sangathan. Prabhawati got a ray of hope when she heard about the new drought tolerant variety Sahbhagi Dhan from her sangathan (SHG). She decided to test the new variety in her farm with the intention that it could be the solution to drought. She received 10 Kg of Sahbhagi Dhan seed under IRRI-UP collaborative demonstration programme during the wet season of 2015 and cultivated it on her own farm. A severe drought spell for more than three weeks incurred at the stage of flowering. During this period she provided two hired irrigations to Sahbhagi Dhan crop. The crop was excellent and yielded about 3.2 t ha⁻¹. However, the adjacent variety Sarjoo 52 was totally damaged even after the provision of two irrigations. "Since many farmers have asked for the seed, but we have decided to share it at community level through our self help group", says Prabhawati.</p>

Table 5. Cont.

Farmer and Site	Cases of Success
Mrs. Meera Kumari, Faridpur, Allahabad, Uttar Pradesh, India	<p>The small land holding female farmer supports her family through rice cultivation. In 2015, she received 10 Kg seed of Sahbhagi Dhan from Motilal Jan Sahyog Seva Samiti, Allahabad and cultivated for the first time on 0.2 ha of land. Severe drought was observed during the months of September and October. In this situation, little loss in grain yield of Sahbhagi Dhan was observed. After harvesting the crop, she recorded the grain yield of 3.4 t ha⁻¹ in Sahbhagi Dhan. However, the other variety Neelkanth which she has planted in adjacent plot was totally damaged due to severe drought. Meera has no irrigation facility, yet she applied three hired irrigations both in Sahbhagi Dhan and Neelkanth. The lady farmer is very happy to be one of the beneficiaries of Sahbhagi Dhan. “Had I not planted Sahbhagi Dhan in my field, I would have faced food crisis”, she expressed.</p>
Mr. Dhananjay Singh, Tajopur, Uttar Pradesh, India	<p>This progressive farmer lives with his wife and four children. He exclusively depends on 1.2 ha of land for all his house-hold expenditures like food, health, children’s education, etc. For several years, Dhananjay has been cultivating Damini, Moti, hybrids and some other local varieties of paddy. He used to harvest only 2.0 to 3.5 t ha⁻¹ every year. At times, due to severe drought, he loses all his rice produce. To overcome the problems, he contacted Nand Educational Foundation for Rural Development (NEFORD), an organization working in his district for farmers’ welfare. He received 25 Kg of Sahbhagi Dhan seed from NEFORD in 2015, which he has planted on 0.6 ha of land. Severe drought spell of 35 days incurred in this area from last week of August to the end of September. Most of the varieties like Moti and Damini got affected by drought even after 4–5 irrigations, but Sahbhagi Dhan remained unaffected with just two irrigations. He obtained the yield of 4.5 t ha⁻¹ from Sahbhagi Dhan. However, Moti and Damini produced only 1.2 t ha⁻¹ and 1.5 t ha⁻¹, respectively. Moreover, the early harvesting of Sahbhagi Dhan ensured longer period for vegetable cultivation in dry season.</p>

12. Conclusions

Due to the long-term adverse impacts of climate change, water deficit is expected to be a major challenge for sustained rice production in the near future. The speculations regarding increase in frequency, intensity and duration of droughts lays serious threat to sustainable rice production, and thence to global food security. The development of rice varieties exhibiting drought tolerance along with better grain yield and desirable quality can serve as the most logical approach to cope up with the menaces inflicted by drought. Besides rapid progress in the development of drought tolerant rice varieties, continuous attempts need to be carried out for dissemination and adoption of these varieties in target environments. The core issues like awareness creation, role of women farmers, and development of strategic public–private partnership need to be addressed to get the best possible benefits from these varieties. We need to ascertain the intentional and strategic partnerships for enhancing the dissemination of drought tolerant varieties to farmers. The support from national system for varietal development, its promotion and policy issues need to address in a very tangible manner. The activities involving the participation of formal seed sector (public and private) and extension systems, ensuring the up scaling and multiplication of STRVs need to be promoted. Besides drought, varieties showing high levels of tolerance to other types of stresses (like submergence, salinity, and cold) should be developed and disseminated in the appropriate target areas. The urgent need is to ascertain strategic plans for developing and disseminating the varieties with multiple stress tolerance such as submergence along with drought for rainfed lowlands and submergence along with salt stress for coastal areas. These varieties can serve as one the most viable and coherent approach for eradicating poverty from the stress prone ecologies.

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