

Sahbhagidhan - The first climate resilient rice variety for drought prone ecosystems

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Climate change scenarios show that higher temperature will lead to lower rice yields as a result of shorter growing period. Heavier rains with longer spells of rainless period will also limit water availability to the crop. Rainfed crops are likely to be worse hit by these events because of the limited mechanisms for coping with variability of precipitation. Even small changes in the rainfall pattern translate into pronounced consequences for rice in terms of reduced crop area, delayed planting with older seedlings and lower production under poor crop nutrition, increased incidence of pests and reduced grain quality. In Jharkhand, Odisha, and Chhattisgarh alone, rice production losses during severe droughts (about one year in five) was about 40% of total production, with an estimated value of \$800 million. Thus, adaptation in rainfed rice production can be seen as a promising entry point to mitigate the consequences of climate change amongst the poorest of the poor. Adaptation to these changes is possible with shorter duration rice varieties, adjustments in the crop calendar with early crop establishment by direct seeding and use of varieties that can withstand longer spells of drought compared to the currently grown varieties.

Keywords: Climate resilient rice variety, Drought-prone area, Sahbhagidhan

RICE research programme at Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Institute, Hazaribagh had focused on rainfed uplands with short growing season and hence the earlier varieties had maturity duration ranging from 90-100 days. The wealth of knowledge and genetic resources accumulated during 1986-2000 from Eastern India indicated that there is a need to differentiate between the unbunded systems and banded uplands where there is a continuum towards the drought prone shallow lowlands. While there was ample scope for crop diversification in the more favourable unbanded uplands, choices for farmer was limited to growing rice in the banded uplands and shallow lowlands during the wet season.

Drought research in collaboration with the International Rice Research Institute under the umbrella of

Upland Rice Research Consortium (URRC) and later the Drought Breeding Network (DBN) emphasized the development of varieties with duration ranging from 80-100 days for the unbanded uplands and 100-110 days for the relatively more favourable banded uplands and shallow lowlands. In the latter case, the focus was on varieties suitable to be grown under direct-seeding or transplanting with higher inputs, depending on the topography, soil type and hydrology.

Genesis

CRURRS, as a partner of the URRC and DBN, had obtained breeding lines selected from several crosses involving drought tolerant lines as parents that included Vandana, Moroberekan, IR 55419-04 and IR 55423-1. Since these breeding lines were derived from crosses involving donors with known

drought tolerance traits and high yield potential in diverse backgrounds, they were presumed to yield good recombinants suitable across large environments.

One such cross between drought tolerant IR 55419-04 and the drought susceptible Indonesian variety Way Rarem yielded several drought tolerant lines with good phenotype. One of the lines, IR 74371-70-1-1 (EC No. 91553) was received from International Rice Research Institute through INGER nursery (IURON) in 2003. This entry was evaluated in IURON during 2003 *kharif* at CRURRS, Hazaribagh and found promising. Single plant selections were made from bulk of INGER nursery for further evaluation and also pure seed multiplication. All these selections were seed multiplied during 2004 *rabi*. In 2004 *kharif*, these lines were evaluated in station trial/preliminary



Fig. 1. Sahbhagidhan flowers

yield trial and also screened for blast and brown spot diseases.

The most promising line designated as IR 74371-70-1-1-CRR-1 was nominated for testing under AICRIP trial IVT-E in 2005. Thereafter, this entry (IET 19576) was tested for three consecutive years in AICRIP trials from 2005 to 2007 *khari*. Based on its performance in multilocation trials under AICRIP, this entry was identified as promising for drought affected areas of Odisha and Jharkhand by AICRIP workshop 2008 and release proposal was submitted by CRURRS, Hazaribagh. Varietal Identification Committee (VIC) recommended the release of this culture in its meeting at Hyderabad in May 2009. Based on the recommendation of the VIC, proposal was submitted for the release and notification of this culture as 'Sahbhagidhan' before CSC on CSN&RV in May 2009. The variety was notified in 2011 for cultivation in Jharkhand and Odisha. Sahbhagidhan was later released as "Sukhadhan 3" in Nepal, and "BRRI dhan 56" in Bangladesh.

Salient Features

Sahbhagidhan flowers in 78-80 days, has intermediate stature (95-100 cm), sturdy stems with 5-8 effective tillers per plant and possess long bold grains (Fig. 1). This variety is resistant to leaf blast and moderately resistant to brown spot and sheath blight diseases. In quality

characteristics, it has high head rice recovery (64.7), high alkali value (7.0), intermediate amylose content (24.68) and medium gel consistency (57 mm). This variety was also tested in farmers' field under participatory varietal selection trials (including sensory evaluation) and liked by farmers. Since Sahbhagidhan was bred for wet-season cultivation, it may not be a suitable variety to be grown in the dry season in areas with low temperatures during germination and seedling stage.

Yield Stability under stress

Sahbhagidhan consistently gave better yield over national and regional check varieties in nationally coordinated trials during 2005-2007. In AICRIP trials, it showed yield advantage of 29.2% and 19.1% over national (Annada) and regional (NDR 97) check varieties under rainfed drought affected conditions and a yield advantage of 22.8% and 31.4% over national and regional checks under non-stressed conditions.

In the India-IRRI Drought Breeding Network breeding trials conducted at eight locations for three years (2005-2007), it showed a yield advantage of 0.5 t/ha under moderate stress and 1.0 t/ha under severe drought conditions over IR64 and IR36, the two prominent varieties grown in this region. Sahbhagidhan yielded at par with these varieties under irrigated control condition. In a stability analysis done over 16

environments in Eastern India, Sahbhagidhan along with one of its sister line were identified as stable genotypes showing high yield under varied environments across different sites.

These lines are derived from a cross between drought-tolerant and drought-susceptible parents and as they were advanced through selection under both non-stress and stress conditions during segregating generations, they have become better adapted to fluctuating environmental conditions. Selection under both situations enabled this variety to maintain greater stability under variable condition and provide high yield under normal conditions and good yield under drought conditions.

Plasticity for different production systems

Because of its adaptability, semi-tall stature, and short duration, crop management recommendations for Sahbhagidhan allow for different seed establishment methods (dry or wet direct-seeded or transplanted) to be used depending on the level of early-season rainfall. Weed menace is undoubtedly a major deterrent for farmers to adopt direct-seeding.

CRURRS introduced Sahbhagidhan to farmers who traditionally practised direct-seeding (villages Arabhusai and Chauria in the district Chatra) and also to those who were inclined to transplant their fields (villages Singrawan and Pathaldiha,

Hazaribag and Koderma districts respectively). The farmers who adopted direct-seeding (DSR) were given the option to either use herbicide (Byspiribac sodium – Nominee Gold) or do ‘*beushaning*’, a practice similar to harrowing using a worn out plough. *Beushaning* is done when sufficient water accumulates in the fields. Interestingly, average yields reported from these villages were similar irrespective of whether the farmers direct seeded or transplanted their crops. DSR farmers had one additional ploughing done a week after pre-monsoon showers which allowed the first flush of weeds to be removed.

Physiology of resilience

Several distinct traits of Sahbhagidhan were observed for resilience behaviour. It has high emergence rates under direct-seeded germination-stage stress, a high proportion of total root length as lateral roots, high harvest index under drought, and high yield stability across wet seasons. Such plasticity in lateral root growth has been highlighted as an important trait for

rice adaptation to the fluctuating soil moisture conditions characteristic of rainfed lowland fields and has been identified as a mechanism by which several drought-tolerant rice genotypes maintain relatively high yields.

Lateral root growth under drought is also one of the most consistent mechanisms observed to be conferred by rice drought-yield quantitative trait locus *qDTY12.1*, which has also been observed to be present in the genome of Sahbhagidhan. The relatively high harvest index of Sahbhagidhan, particularly under drought stress also helps to explain its high and stable yield across environments. Lack of a stay-green phenotype in Sahbhagidhan, as evidenced by the low end-of-season normalized difference vegetation index (NDVI), further points to remobilization of stored carbohydrates as a potentially important mechanism for grain filling in this variety.

Accelerated dissemination

Bundled uplands and shallow lowlands occupy a substantial part of

the agricultural landscape in the predominantly rainfed regions of Eastern India. The rainfed ecosystems are home to economically and socially disadvantaged communities with poor access to seeds and information. Hence, it is imperative that newer varieties developed are demonstrated to the farmers in relatively larger farm fields under farmer managed conditions. The BMGF funded project on Stress Tolerant Rice for Africa and South Asia (STRASA), with a mandate to cover three million farm families in the first three years of the project co-opted many government and non-governmental agencies for large scale demonstrations of stress tolerant varieties, especially Swarna *Sub-1* for flood prone areas and Sahbhagidhan for drought prone areas. The phenomenal success of the programme in its first phase in reaching out to a large clientele prompted the funding agency to extend the project for two more successive phases.

An intensive seed production program was undertaken to disseminate this variety in drought-prone regions of eastern India in collaboration with CRRRI-CRURRS, SAUs, NSC, state seed corporations and various NGOs. The variety was released by VIC in 2009 and approximately 2.5 tonnes of breeder seed was available by the end of 2009 *kharif*. NSC along with Odisha State Seed Corporation undertook a large-scale seed multiplication at Bargarh during *rabi* and increased the quantity to more than 100 tonnes before the wet season of 2010. CRURRS, Hazaribag has produced 1973.6 quintals of breeder seed of Sahbhagidhan during 2011-2020 (Fig. 2).

The Odisha State Seed Corporation has taken the maximum breeder seeds (about 100 quintals every year) and produced large quantity of foundation/certified seeds. Next to Odisha is Bihar, followed by Uttar Pradesh and West Bengal. Bulk of the seeds produced in Odisha also catered the need of the adjoining state like Chhatisgarh, where Sahbhagidhan is also grown on a large scale.

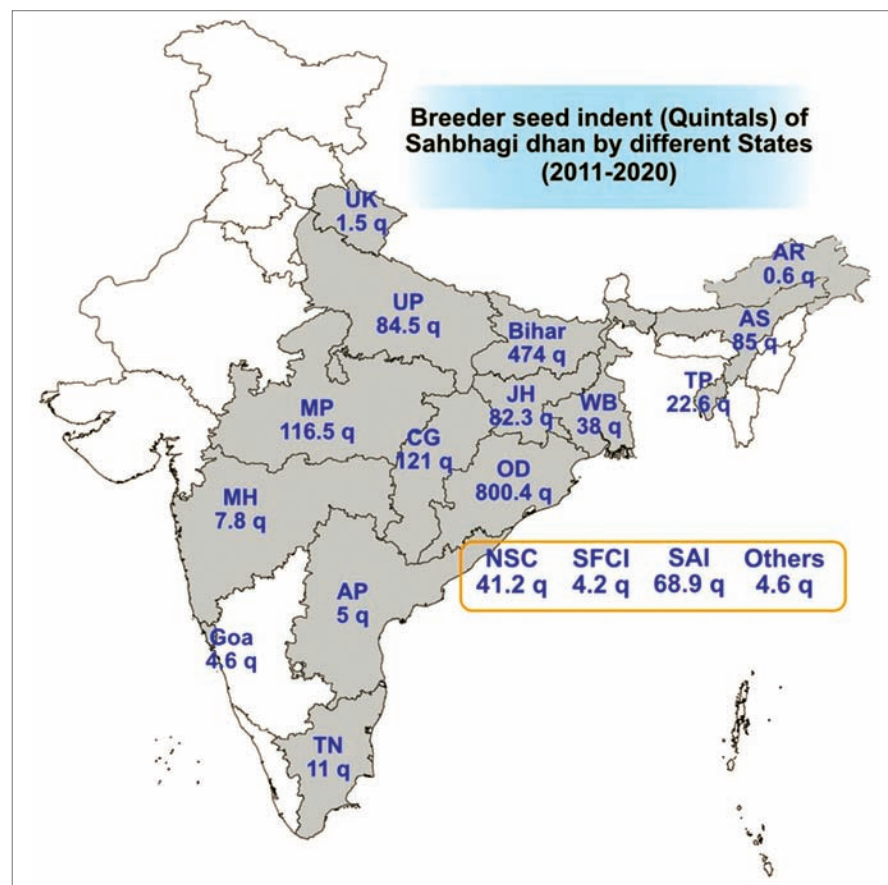


Fig. 2. Breeder seed indent from different states for Sahbhagidhan (2011-20)

The National Food Security Mission had chosen Sahbhagidhan for large scale promotion during *kharif* 2010 through their minikits program. They distribute the minikits of Sahbhagidhan in drought-prone areas of Jharkhand, Bihar, Chhattisgarh, Uttar Pradesh, Odisha and West Bengal. Phenomenal success of the programme in reaching out to a large clientele which helped the spread of Sahbhagidhan to whole Eastern India. Under NFSM, Sahbhagidhan was demonstrated in 1,700 ha in Odisha, West Bengal, Jharkhand, Uttar Pradesh and Bihar (Table 1). The variety performed exceptionally well under normal as well as drought or less rainfall conditions with an overwhelming response from the farmers (Table 2). All farmers harvested excellent crop, yielding significantly higher than other varieties. In Purulia district of West Bengal, the variety yielded exceptionally good and surprised the farmers about its yield potential in 105 days duration under both good rainfall as well as scanty rainfall conditions.

The average yield of Sahbhagidhan was 4.47 t/ha in 105 days as compared to Lalat which yielded 2.86 t/ha in 120 days. Lalat is a common rice variety grown in the upland rice ecology of West Bengal and Odisha. As reported in January 2013, about 12.5 % of the produce of this variety was saved by the farmers as seed for the use during the next crop season. However, under the favourable rainfed conditions, the benefits of the variety are enormous. In Uttar Pradesh, this variety yielded 4.5 t/ha in 105 days as compared to 3.7 t/ha in Sarju 52 which is the most popular variety of the eastern Uttar Pradesh.

Farmers also saved the cost of a couple of additional irrigations provided to Sarju 52 apart from harvesting the crop earlier. This enabled them to sow wheat earlier which benefits in harvesting better yields than late sown. Some farmers could manage to timely cultivate potatoes to fetch the better price. About 8% of the produce of Sahbhagidhan has been saved by the farmers for personal use or exchanged

Table 1. State wise average productivity of Sahbhagidhan and yield advantage over other varieties

States	Total area Sahbhagidhan (ha)	Productivity Sahbhagidhan (t/ha)	Productivity neighbour's field (t/ha)	Yield advantage (t/ha)	Produce used as seed (%)
West Bengal	50	4.47	2.86	1.07	12.46
Uttar Pradesh	900	4.50	3.70	0.80	8.04
Odisha	850	3.57	2.56	1.01	4.85
Bihar	700	4.50	3.22	1.29	8.9
Jharkhand	600	4.41	2.2	1.2	3
Total/Average	3100	4.29	2.9	1.07	7.4

Source: NFSM report 2013-14

Table 2. Performance of Sahbhagidhan under stress condition

Drought days	Demonstrative variety yield (t/ha)	Adjacent variety yield (t/ha)	Yield advantage (t)
<i>Uttar Pradesh</i>			
10-12 d	4.35	3.58	0.78
13-15 d	4.57	3.60	0.97
16-18 d	4.45	3.65	0.80
<i>West Bengal</i>			
	4.45	2.77	1.67
	4.83	2.93	1.89
	4.04	3.20	0.84

Source: NFSM report 2013-14

with the fellow farmers in the ratio of 1:10. Equally good response was received from the tribal district of Mayurbhanj in Odisha. Here, farmers realized that this variety could be very important for its yield performance under less water conditions. Moreover, the early maturity could allow them to go for rice-pulse system. At the time of the harvest of this variety, the residual moisture is just appropriate for the pulse germination and growth. The late duration varieties in these areas have yielded less (2.56 t/ha) than Sahbhagidhan (3.57). In Bihar, where rainfall was good, Sahbhagidhan yielded higher than other places. Farmers showed overwhelming response to the variety due to its short duration and high yield potential under stress and non-stress conditions. It was reported that about 8.9% produce was sold for use as seed with a diffusion ratio of 1:8 farmers.

SUMMARY

In recent years, because of the frequent occurrence of drought stress, there is yield decline in rice, and the climate change predicts that water deficit will further deteriorate in the coming years. To stabilize the production in the rainfed drought-prone areas, there is a growing need

for climate resilient technologies which can tolerate the vagaries of weather. Drought tolerant varieties provide opportunities for improving and stabilizing productivity in drought-prone areas, thereby contributing to National Food Security. Due to sustained efforts made by the Ministry of Agriculture and Farmers Welfare and partners through different schemes, Sahbhagidhan has been extensively spread to the farmers leading to its large-scale adoption. Because of its shorter duration, this variety provides a window of opportunity for increasing cropping intensity to enhance overall productivity under both the rainfed and irrigated ecosystem. The unique feature of Sahbhagidhan is its climate resiliency, not only this variety showed high tolerance against drought but also there is no yield penalty when grown under non-stress condition in comparison to other varieties of similar duration, making it one of the attractive option for stress-prone ecology. Large scale adoption of this variety will not only enhance but also stabilize the rice production in drought-prone areas of the country.

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