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Popularization of climate-resilient Sali rice varieties among the farmers in Morigaon and Darrang districts of Assam

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Abstract
The agricultural sector in Assam faces increasing vulnerabilities due to recurrent floods and erratic rainfall patterns, significantly impacting rice production, a staple crop in the region. This study focuses on the popularization and adoption of climate-resilient Sali rice varieties, Bahadur-Sub1 and Ranjit-Sub1, among farmers in the flood-prone districts Morigaon and Darrang of Assam. Utilizing On-Farm Trials (OFTs) and Frontline Demonstrations (FLDs), the research assessed these varieties' performance in terms of yield stability, submergence tolerance, economic viability, and farmers adoption.
The results revealed that Bahadur-Sub1 and Ranjit-Sub1 outperformed traditional rice varieties, with an average yield increase of 28-35%, maintaining yield stability despite submergence for 10-15 days. The varieties demonstrated survival rates of over 80% under submerged conditions, compared to 54% for local varieties. Economic analysis indicated higher average net returns (Rs. 33,625/ha) and benefit-cost ratios (1.58 to 2.20) for the resilient varieties, highlighting their financial viability. Farmer surveys conducted post-demonstration showed a significant increase in awareness and willingness to adopt these varieties, with 70% of participating farmers expressing intent for future cultivation.
The study underscores the potential of climate-resilient rice varieties to enhance productivity, mitigate climate-induced risks, and improve farmer livelihoods in flood-prone regions. It also highlights the need for targeted policy interventions, improved seed accessibility, and robust extension services to promote widespread adoption. These findings contribute to the broader discourse on climate adaptation in agriculture and offer actionable insights for sustainable rice farming in vulnerable agro-climatic zones.

Keywords: Bahadur Sub-1, Ranjit Sub-1, OFT, FLD, Yield, Economic analysis

Introduction
The impacts of climate change on agriculture have become an increasingly pressing global concern, with rising temperatures, erratic rainfall patterns, and extreme weather events jeopardizing the stability of food systems. In India, where agriculture contributes significantly to livelihoods and the national economy, these changes have had profound effects, particularly on rice cultivation, which is highly sensitive to climatic variations. Assam, a key rice-producing state in Northeast India, exemplifies this challenge. The state's agricultural sector, dominated by small and marginal farmers, faces recurrent threats from floods, droughts, and fluctuating weather patterns, which are projected to intensify under changing climate scenarios (IPCC, 2021).
Assam is a land of agriculturally rich heritage which is divided into six agro-climatic zones. Morigaon district falls under Central Brahmaputra Valley Zone which receives an average annual rainfall of 1,800-2,300mm (IMD, 2021), whereas Darrang district comes under North Bank Plain Zone with annual average rainfall of 1,700-2,100 mm (IMD, 2021). The rainy days in the districts prevails from the month of April to mid October (http://cgwb.gov.in/District_Profile/Assam).Periods of intense precipitation leads to recurrent flooding, submerging vast swathes of agricultural land, while intermittent dry spells disrupt the sowing and growth stages of crops. For instance, the devastating floods 2022 in these districts caused substantial damage to standing crops, with Morigaon alone witnessing over 75% of

cultivable land area inundated, and the statistics for Darrang was 68% (ASDMA, 2022). Such events underscore the urgent need for adaptive agricultural strategies to safeguard livelihoods and food security.

Sali rice, a primary crop in Assam, plays a central role in ensuring food security in the region. However, the increasing unpredictability of climatic conditions has resulted in reduced productivity and heightened vulnerability of traditional Sali rice varieties. Monocropping is prevalent in the majority of the areas. During Sali season because of the retention of flood waters in the field the yield of long duration sali paddy is badly affected.Mostly long duration local varieties are being practice by the farmers and only 10-15 percent area is devoted to high yielding varieties, for which the productivity becomes low, the reliance on traditional rice varieties has rendered these farmers increasingly vulnerable to climate extremes. Addressing this issue necessitates the adoption of climate-resilient rice varieties tailored to withstand biotic and abiotic stresses, such as flooding, drought, and salinity. Among these, climate-resilient Sali rice varieties, including submergence-tolerant strains such as *Ranjit sub-1*, have demonstrated considerable potential to enhance crop stability under adverse conditions (Ismail *et al*., 2013) [11]. Farmers of the district would be benefitted if they can grow at least two to three crops in a year. Since flooding is one of the major hazards of rice cultivation in Brahmaputra basin areas, tolerant varieties are urgently needed to help protect the farmers from submergence. The technologies offering resilience to then changing climatic context of agriculture become an imperative to the sector and its dependents secured (Jasna *et al.*, 2017) [12].

It is of utmost importance that farmers get benefitted by short or medium duration sali paddy varieties so that they can go for their Rabi crops at proper time. The commercially grown rice in Assam is the *Oryza sativa* family, comprising of Indica rice race. Indica - It is the major eco-geographical race of *Oryza sativa* grown in Assam. These Sub1 varieties are now spreading at an unprecedented pace in Assam and are expected to cover the entire area in the near future. These Sub1 varieties also encourage farmers to use more inputs. Thus, they have the potential to usher a second green revolution in the flood-prone rainfed rice areas, which did not benefit from the first green revolution initiated during the mid-sixties. Therefore keeping this in view the sub-1 varieties where tested as On Farm Trial in the year 2016-17 followed by popularization through Frontline Demonstration in larger area with subsequent quality seed production in participatory mode from the year 2017-18 to 2021-22 respectively. Moreover, the findings aim to provide actionable insights for policymakers and stakeholders to enhance climate adaptation and build resilience in Assam's rice farming systems.

Materials and Methods

The study was conducted in the Morigaon and Darrang districts of Assam, located in Central Brahmaputra Valley Zone and North Bank Plain Zone respectively. Morigaon, with its proximity to the Brahmaputra River and the Kopili River and Darrang, traversed by the Jiabharali and Nanoi rivers, are prone to flooding and other climate-induced challenges, making them ideal locations for studying the impact of climate-resilient rice varieties. Both districts are predominantly agrarian, with rice being the primary crop.

The research utilized a participatory approach, combining On-Farm Trials (OFTs) and Frontline Demonstrations (FLDs) to assess the performance, adoption potential, and impacts of climate-resilient Sali rice varieties (Ranjit Sub-1, Bahadur sub-1). A total of 5 OFTs and 12 nos of FLDs were conducted at Borsola, Santipur, Burakuwargaon, Gaolia, Manaha, Rupohiborinigam, Jurgaon, Kalshilapar, Ouguriarea in the Morigaon district covering an area of 6.48 ha in the year 2017-18 to 2019-20 respectively. And 14 nos of OFTs were done at Gargari, Mahaliapara, Dahi-Nagaon, Niz-Rangamati, Na-Hawli, Borthekerabari villages of Darrang district covering an area of 6.46 ha to gather both empirical data on crop performance and practical insights from farmers.

Standard agronomic practices recommended by the Assam Agricultural University (AAU) were followed for both the climate-resilient and traditional varieties. This included land preparation, seed treatment, irrigation, and pest management. Farmers were provided with training on the selection, sowing, and management of the resilient rice varieties. Field days and demonstrations were conducted at critical growth stages to ensure practical learning

Table 1: Parentage, seasonal suitability and varietal characters of different varieties tested under OFT & FLDs

Variety	Parentage	Seasonal suitability	Varietal characters
Swarna Sub 1	Swarna 3 x IR 49830-7-1-2-3	Winter (Kharif)	Submergence tolerant for 10-15 days, Photo sensitive, crop duration 140-145 days, husk colour is much lighter than Swarna and whitish in colour so called as Dhalaswarna
Ranjit Sub 1	Ranjit x swarna sub-1	Winter (Kharif)	Submergence tolerant for 10-15 days, Photo sensitive, crop duration 150-155days, Semi dwarf (99 cm) plant with quality grain of short fine, tolerant to BLB, susceptible to blast, SB & GM yield: 50 q/ha
Bahadur Sub 1	Bahadur X Swarnasub-1	Winter (Kharif)	Submergence tolerant for 10-15 days, Photo sensitive, crop duration 150-155days, Semi dwarf (114 cm) plant with compact panicle with brown husk colour, AWP, resistant to LB, tolerant to neck blast, BLB, moderately susceptible to GM yield: 50 q/ha

Table 2: Detail information about the demonstrations conducted during kharif in rainfed medium land in different years

Year of study	District	Variety	Area(ha)	No. of demonstrations	Date of sowing	Date of harvesting	Submergence days
2016-17	Morigaon	Ranjit sub-1	0.13	1	9.6.2016	26.11.2016	12 days
		Bahadur sub-1	0.53	4	19.7.2016	16.11.2016	12 days
		Swarna Sub-1	0.13	5	9.6.2016	18.11.2016	12 days
	Darrang	Ranjit sub-1	0.53	3	31.05.16	09.11.16	5 days
		Bahadur sub-1	0.10	1			5 days
2017-18	Morigaon	Ranjit Sub-1	1.00	3	13.7.2017	06.12.2017	8 days
		Bahadur sub-1	1.00	3	16.7.2017	8.11.2017	8 days
		Swarna Sub-1	0.4	3	10.7.2017	04.12.2017	8 days
	Darrang	Ranjit sub-1	0.2	2	10.06.17	16.11.17	4 days

		Bahadur sub-1	0.2	1	10.06.17	20.11.17	4 days
2018-19	Morigaon	Ranjit Sub-1	0.8	3	05.7.2018	06.12.2018	3 days
		Bahadur sub-1	0.8	3	05.7.2018	29.11.2018	3 days
		Swarna Sub-1	0.4	3	05.7.2018	25.11.2018	3 days
	Darrang	Ranjit Sub-1	0.33	3	14.06.18	20.11.18	5 days
		Bahadur sub-1	0.20	2	14.06.18	22.11.18	5 days
2019-20	Morigaon	Ranjit Sub-1	0.66	2	10.7.2019	9.12.2019	7 days
		Bahadur sub-1	0.66	2	12.7.2019	5.12.2019	7 days
		Swarna Sub-1	0.66	2	09.7.2019	23.11.2019	7 days
	Darrang	Ranjit Sub-1	3	5	15.06.2019	20.11.2019	6 days
		Bahadur sub-1	2	5	15.06.2019	25.11.2019	6 days

In farmer's plots, farmer's traditional practices were recorded. Yield and yield attributing characters were observed. The economic parameters were calculated based on the prevailing market price of the inputs and minimum support prices of outputs.The data output from OFT and FLDs with comparison from control plots and extension gap, technological gap, technological index along with the benefit-cost ratio were calculated using the formula as given by *Samui et al* (2000) [16]. Details of farming situation, soil type, date of sowing, date of harvesting, and submergence days during the crop season for respective OFT & FLDs are mentioned in Table 2.

- **Extension gap** = Demonstration yield- farmers' yield (control)
- **Technology gap** = Potential yield- demonstration yield
- **Technology index** = (Technology gap /Potential Yield) × 100
- **B:C** = Net income (Rs./ha)/Cost of cultivation(Rs./ha)

Results and Discussion

The study demonstrated the significant potential of climate-resilient rice varieties *Ranjit-Sub1*and *Bahadur sub-1* in enhancing agricultural productivity and resilience in the flood-prone districts of Morigaon and Darrang in Assam. Results from the On-Farm Trials (OFTs) revealed that both varieties significantly outperformed traditional rice varieties in terms of yield, flood tolerance, and economic returns. The superior performance of *Bahadur-Sub1* and *Ranjit-Sub1* highlights their potential to address the challenges posed by climate change, particularly in flood-prone regions like Morigaon and Darrang. The results are consistent with previous studies (Pathak & Singh, 2019) [15], which reported similar yield advantages and submergence tolerance of *Sub1* varieties in the North Bank Plain Zone of Assam. These varieties exhibited enhanced anaerobic germination and resilience, allowing them to recover and sustain productivity under submerged conditions.

The On Farm Trial of the two varieties Ranjit Sub 1 and Bahadur Sub 1 grown during kharif 2016-17 showed complete submergence for 12 days in one location at seedling stage in nursery bed only in the district of Morigaon. Also, it was sown lately due to initial flood while in other locations the same varieties were under continuous submergence for 12 days at tillering stagein the same year in Morigaon district. It has been observed that the varieties which were submerged at nursery bed and other one at tillering stage survived. The result was found to be much better with 52 q/ha and 53 q/ha from Ranjit Sub 1 and Bahadur Sub 1 respectively. This may be due to silt deposition after flood. The finding has conformity with findings of Ranjita Bezbaruah (2019) [3]. In Morigaon, by observing the performance of yield and other characters of the OFT, consecutively for three years from 2017-18 to 2019-20 twenty four numbers of Frontline Demonstrations were conducted covering an area of 6.48 ha. For conducting FLDs SwarnaSub-1 variety was taken as local check since this variety gained popularity some 5 years back in the district Morigaon before the trial as OFT. In the year 2017-18 the varieties Ranjit sub -1 and BahadurSub-1 showed a yield of 49.9 q/ha and 53.5 q/ha against check of 44.2q/ha respectively despite of submergence of eight days just after transplanting stage. During the kharif season in the year 2018-19 the two varieties Ranjit Sub-1 and Bahadur Sub-1 showed a yield of 51q/ha and 53 q/ha respectively against Swarna sub-1 as check of 46q/ha. In the year 2019-20 there was flash flood continuously for 7 days and the two varieties Ranjit Sub-1 and Bahadur Sub-1 showed an yield of 50.8 q/ha and 52.81 q/ha respectively against check of 45.2q/ha.

In the district of Darrang, Jalkunwari was considered as check variety. In 2016-17, the yields of Bahadur sub-1 and Ranjit sub-1 were 45.3 and 48.2 q/ha, respectively. Although the cultivars Ranjit Sub-1 and BahadurSub-1 were submerged for five days immediately following the transplanting stage, they produced 48.4 q/ha and 47.27 q/ha, respectively, in 2017-18, compared to a check of 41 q/ha. In comparison to Jalkunwari, which yielded 41.8 q/ha during the 2018-19 kharif season, the two varieties Ranjit Sub-1 and Bahadur Sub-1 produced 50.2 q/ha and 48.5 q/ha, respectively. The crops were flooded for six days in 2019-20, and Ranjit Sub-1 and Bahadur Sub-1 produced 52 and 53 q/ha, respectively, compared to a check of 36 q/ha.

The grain yield performance with gap analysis has been shown in Table 3.

Table 3: Grain yield performance of submergence tolerant varieties

Year	District	Variety	Yield(Q/ha)			Percent increase over farmers practice	Technology gap(Q/ha)	Extension gap(Q/ha)	Technology index (%)
			Potential	Recommended practices	Farmers practice				
2016-17	Morigaon	Ranjit sub-1	58.00	52.00	not survived	100	6.00	52.00	10.34
		Bahadur sub-1	58.00	53.00	not survived	100	5.00	53.00	8.62
	Darrang	Ranjit sub-1	58.00	48.2	39.2	22.95	9.8	9	16.89
		Bahadur sub-1	58.00	45.3	39.2	15.56	12.7	6.1	21.89
2017-18	Morigaon	Ranjit Sub-1	58.00	49.90	44.20	12.89	8.10	5.70	13.96
		Bahadur sub-1	58.00	53.5	44.20	21.04	4.5	9.3	7.75
	Darrang	Ranjit Sub-1	58.00	48.40	41	18.04	9.6	7.4	16.55
		Bahadur sub-1	58.00	47.27	41	15.29	10.73	6.27	18.50
2018-	Morigaon	Ranjit Sub-1	58.00	51.00	46.00	10.86	7.00	5.00	12.06

19		Bahadur sub-1	58.00	53.00	46.00	15.21	5.00	12.00	8.62
	Darrang	Ranjit Sub-1	58.00	50.2	41.8	20.09	7.8	8.4	13.44
		Bahadur Sub-1	58.00	48.5	41.8	16.02	9.5	6.7	16.37
2019-20	Morigaon	Ranjit Sub-1	58.00	50.08	45.20	10.79	7.92	4.88	13.65
		Bahadur sub-1	58.00	52.81	45.20	16.83	5.19	7.61	8.94
	Darrang	Ranjit Sub-1	58.00	52	36	44.44	6	16	10.34
		Bahadur sub-1	58.00	53	36	47.22	5	17	8.62

Gap analysis

Present study (Table 3) revealed that an extension of 1.00 q/ha to 8.10 q/ha was found between demonstrated technology and farmers practice. The extension gap for Ranjit sub-1 was highest in the year 2017-18 and lowest in the year 2016-17 whereas for Bahadur sub-1 gap was highest in 2016-17 and lowest in 2018-19.The adoption of scientific cultivation practices in demonstration plot might be the reason which resulted in higher grain yield than farmer's practices. The wide technology gap during the OFT and FLDs year of implementation may be due to soil fertility status and weather conditions. This extension gap necessitates the need to bring awareness among the farmers for adoption of improved submergence tolerant rice varieties (Singh *et al*., 2018) [18]. These are similar to findings of Patel *et al* (2013) [14], Bezbaruah R (2019) [3] and Gaur *et al* (2020) [7].

In the study the Technology Index showed feasibility of the technology at farmer's field. On an average based on the demonstrations 7.25 % was recorded. Lower technology index reflected the adequate transfer of proven technology to growers and sufficient extension services for transfer of technology and is because of adoption of improved package of practices with scientific cultivation practices. (Chauhan, 2011) [5]. These similar findings were found by Rupsikha *et al*, 2020 and Bezbaruah R (2019) [3].

Table 4: Economics of the demonstrations

Year	District	Variety	Cost of Cultivation (Rs/ha)	Gross Return (Rs./ha)	Net return (Rs/ha)	B:C ratio
2016-17	Morigaon	Ranjit sub-1	25000	67500	45000	2.15
		Bahadur sub-1	25500	77500	42000	2.07
	Darrang	Ranjit sub-1	26000	51480	25480	1.98
		Bahadur sub-1	26000	49660	23660	1.91
2017-18	Morigaon	Ranjit Sub-1	25000	52500	27500	2.1
		Bahadur sub-1	25500	51000	25500	2.0
	Darrang	Ranjit Sub-1	27100	59620	32520	2.2
		Bahadur sub-1	27100	53929	26829	1.9
2018-19	Morigaon	Ranjit Sub-1	27000	52650	25650	1.95
		Bahadur sub-1	27000	55350	28350	2.05
	Darrang	Ranjit Sub-1	30000	59700	29700	1.99
		Bahadur sub-1	30000	57300	27300	1.91
2019-20	Morigaon	Ranjit Sub-1	38500	60960	22460	1.58
		Bahadur sub-1	38500	68175	29672	1.77
	Darrang	Ranjit Sub-1	37200	71250	34050	1.91
		Bahadur sub-1	37200	67500	30300	1.81

Economics

The economic viability of adopting climate-resilient Sali rice varieties, *Bahadur-Sub1* and *Ranjit-Sub1*, was analyzed using the benefit-cost ratio (BCR) to assess their financial performance compared to traditional rice varieties in the Morigaon and Darrang districts of Assam. The results revealed a clear economic advantage for farmers cultivating the resilient varieties, particularly in flood-prone areas. The BCR values for *Bahadur-Sub1* and *Ranjit-Sub1* were significantly higher than those of the traditional varieties, indicating that these climate-resilient varieties offer better financial returns under similar input conditions. The increased returns can be attributed to higher yields, better tolerance to submergence, and reduced crop losses due to flooding.The findings align with those of Singh and Sharma (2016) [19], who reported a similar economic advantage for Sub1 varieties in flood-prone regions. Similar results were found by Rupsikha *et al*, 2020 and Bezbaruah R (2019) [3] in case of submergence tolerant rice varieties of Assam.

Conclusion

The promotion and adoption of climate-resilient Sali rice varieties, such as *Bahadur-Sub1* and *Ranjit-Sub1*, in Morigaon and Darrang districts of Assam, demonstrate a promising pathway for enhancing agricultural sustainability in the face of climate change. The study's findings highlight the superior yield performance, submergence tolerance, and economic viability of these varieties, making them highly suitable for flood-prone agro-climatic zones. On-Farm Trials (OFTs) and Frontline Demonstrations (FLDs) effectively demonstrated the practical benefits of these varieties to farmers, leading to significant interest and intent for adoption

The increased yield stability, coupled with higher benefit-cost ratios, underscores the potential of these varieties to improve farmers' incomes and livelihoods, even under adverse climatic conditions. By mitigating the impacts of floods, these varieties play a crucial role in ensuring food security and promoting climate-resilient agriculture. However, challenges such as limited seed availability, lack of awareness, and market dynamics must be addressed to maximize their adoption and impact.

This research emphasizes the need for robust extension services, policy support, and targeted interventions to scale up the adoption of climate-resilient rice varieties. Integrating these innovations into broader agricultural development programs will not only strengthen farmers' adaptive capacity but also contribute significantly to achieving sustainable agricultural practices and climate adaptation goals in Assam and similar regions. The insights from this study serve as a foundation for future research and policy-making aimed at building resilient farming systems in the era of climate change.

Conflicts of interest
The authors have no conflicts of interest.

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