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Direct seeded rice: A cutting-edge solution for climate change, food security, and enhanced resource efficiency

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Abstract
Sonitpur district, located in the north bank plain agro-climatic zone of Assam, is characterized by its geographical boundaries. To the north lies Kameng district of Arunachal Pradesh, while the Brahmaputra river marks the southern border. Lakhimpur district is situated to the east, and Darrang district to the west. The district is positioned between 26.28-27.08 degrees north latitude and 91.19-93.47 degrees east longitude, encompassing a total area of 5204 square Kilometers.
In terms of climate, Sonitpur falls within the subtropical region and experiences a monsoon-type climate. The district boasts a significant cultivable area spanning 111,949 hectares, with rice being the primary crop, constituting approximately 48.54 percent of the total cropped area. The cultivation of summer paddy, winter paddy, and autumn paddy covers 22,500 hectares, 124,523 hectares, and 12,488 hectares, respectively, with corresponding productivities of 5062 kg/ha, 3048 kg/ha, and 2793 kg/ha. To address the concerns of farmers regarding production costs and climate vulnerability, Krishi Vigyan Kendra, Sonitpur introduced the direct seeding of rice cultivation in select pockets of the district. By employing the stress-tolerant rice variety Ranjit-Sub1 through wet direct seeding, the district witnessed improved remuneration compared to conventional rice cultivation. Economic analysis revealed higher net returns (X and Y) for wet direct seeded rice (WDSR) in both 2018-2019 and 2019-2020, in contrast to the farmer's practice. Additionally, the B: C ratio was also favorable for wet direct seeded rice (WDSR). This climate-resilient technology proved highly promising for small and marginal farmers in the region, significantly impacting their agricultural practices.

Keywords: Direct seeded rice, wet direct seeded rice (WDSR), water use efficiency, Greenhouse gas, weed management

1. Introduction
Rice (*Oryza sativa* L.) is the dominant food crop in Assam, both in terms of production and its impact on the economy. It is cultivated across various ecological conditions in the region. Traditionally, there are two methods of planting rice. The first is the conventional transplanting method, which involves preparing nursery beds, raising seedlings, uprooting them, and transplanting them into the main field. The second method is direct seeding, which can be done through broadcasting or by using a drum seeder. In the conventional practice, the nursery bed needs to be prepared a month before transplanting into the main field, as timely preparation and transplanting play crucial roles in this method. A delay of one month in transplanting can lead to a 25% reduction in yield, and a delay of two months can cause a 70% reduction in yield. Farmers who follow conventional rice cultivation methods face numerous challenges during the peak season, such as labor shortages, increased labor costs, and the unavailability of other inputs. Furthermore, this practice deteriorates soil properties, negatively affects succeeding crops, and contributes to methane emissions.
Published studies have shown that direct seeding offers several advantages over puddled transplanted rice (PTR), including similar yields, water and labor savings, reduced production costs, higher net economic returns, and decreased methane emissions. Therefore, there is a growing need to shift from puddled transplanting to direct seeding of rice. However, there have been variations in yields, particularly with dry direct seeding, due to issues such as uneven and poor crop stand, inadequate weed control, high spikelet sterility, crop lodging, and limited knowledge of water and nutrient management. Additionally, the rice varieties currently used for direct seeding were primarily selected and bred for transplanting.

Direct seeding of rice (DSR) is a resource-conserving technology that reduces water and labor usage by 50%. It presents an exciting opportunity to improve water and environmental sustainability, with lower methane emissions compared to conventional puddled transplanted rice. DSR involves sowing pre-germinated seeds in puddled soil (wet seeding), standing water (water seeding), or dry seeding in a prepared seedbed. Precise water management, especially during the crop emergence phase (1st 7-15 DAS), is crucial in DSR. Weed infestation poses a major challenge in DSR, causing significant yield losses. Weed management in DSR can be addressed through chemical, manual, or stale seed bed methods. In continuous conventional puddled transplanted rice, the situation is exacerbated by damaged soil structure, leading to decreased land and water productivity. DSR provides an opportunity to practice conservation agriculture (CA) in rice-based cropping systems, with dry direct-seeded rice (Dry DSR) helping improve soil health by enhancing physical properties (reducing bulk density, increasing porosity, and available water content), chemical properties, and the soil's microbiome.

2. Materials and Methods

Sonitpur district, situated in the subtropical climatic region, experiences a well-defined monsoon season. The summers are hot and humid, with an average temperature of 29°C. The highest temperatures occur just before the onset of the monsoon, usually in May or early June. During summer, heavy rainfall, primarily brought by the moisture-laden South West Monsoon, occurs when it reaches the foothills of the Himalayas to the north. While these rains provide natural irrigation to the fields, they also pose a risk of floods. Autumns in the district are dry and warm. As October approaches, the temperature drops, and from October to February, it becomes cold and generally dry, with an average temperature of 10 °C. Late December and early January can be quite chilly due to snowfall in the upper reaches of Arunachal Pradesh. The district experiences extreme rainfall, temperature, and relative humidity, with values such as 375.9 mm of rainfall in July, 14 mm in December, 32.7°C in August, 10°C in January, 85.2% humidity in August and September, and 64.8% humidity in March.

Due to the heavy rainfall experienced in Sonitpur district, especially during crop establishment, farmers in the region face significant challenges. To address this, a stress-tolerant rice variety (STRV) called Ranjit-sub1, developed by Assam Agricultural University in Jorhat, was introduced in selected areas of the district. Ranjit-sub1 is a long-duration variety, capable of surviving floods for up to 15 days from the date of sowing. Traditional rice varieties used by farmers in the district are unable to withstand prolonged flooding and eventually die after 5-6 days, resulting in substantial yield losses. Yield and yield attributing characteristics of Ranjit-sub1 were compared with the farmers' own variety (Mahsuri) in some areas where floodwater appeared for only 2-3 days.

Demonstrations were conducted in a specific area, covering a certain number of farmers, to analyze the potential and feasibility of Direct Seeding Rice (DSR) technology and STRV during the sali season of 2018 and 2019, respectively. In the demonstrated plots, seeds were sown using a five-row paddy drum seeder. The seeds were soaked for 24 hours and incubated for 24-48 hours before sowing using a perforated drum seeder. Farmers' practice involved conventional transplanting. All inputs, including seeds, fertilizers, pesticides, bio pesticides, and weedicides, were provided to both the demonstrated plots and the farmers' variety plots. The cost of cultivation for both technologies was studied and compared. Data on various parameters, such as plant height, plants per square meter, tillers per square meter, straw yield per 5 square meters, and grain yield per 5 square meters, were collected from different demonstration plots and farmers' practice plots over two years. The average data from the demonstrated varieties and the farmers' variety were compared. Crop yield data were recorded randomly from 3-4 places for both the demonstrated and farmers' varieties. Economic analysis was also conducted for both conventional cultivation and direct seeding technology, including a study of the benefit-cost ratio, to assess and compare the two approaches.

3. Results and Discussion

The cost of cultivating paddy through manual transplanting and direct seeding was thoroughly examined and presented in Table 1. Upon reviewing Table 1, it becomes apparent that the cost of preparing nursery beds for manual transplanting amounted to Rs. 1000.00, while direct seeding required no such preparation. Moreover, it can be inferred from the table that labor charges for sowing (Rs. 1250.00) and weeding (Rs. 1000.00) were reduced in direct seeding compared to manual transplanting due to the utilization of mechanical paddy transplanters and power weeders.

The table 1 also reveals that the expenses incurred for plant protection were lower in direct seeding (Rs. 1500.00) compared to manual transplanting (Rs. 2000.00). This can be attributed to the maintenance of proper row-to-row and plant-to-plant spacing in direct seeding. Previous studies have demonstrated that the use of power weeders in paddy fields reduces pest and disease incidence. Weeds often harbor pathogens during the off-season, acting as a source of infection for the main crop during its growing season. By significantly reducing weed percentage, power weeders contribute to improved yield performance. According to Rajendran *et al.* (2018) [2], the use of power weeders increases the sprouting of additional tillers per hill by providing better root aeration and enhancing nutrient uptake, ultimately resulting in higher yields compared to conventional techniques.

Furthermore, the study revealed that the average plant height (cm), number of plants per square meter, number of tillers per square meter, number of panicles per square meter, straw yield (kg) per square meter, and grain yield (kg/ha) of the Ranjit-sub1 variety in direct-seeded plots were 119 cm, 30, 390, 370, 2.3 kg/m², and 5200 kg/ha, respectively, during 2018-19, and 118 cm, 28, 392, 375, 2.18 kg/m², and 5025 kg/ha, respectively, during 2019-20. In the farmers' practice plots, where Mahsuri was cultivated, the average plant height (cm), number of plants per square meter, number of tillers per square meter, number of panicles per square meter, straw yield (kg) per square meter, and grain yield (kg/ha) were found to be 105 cm, 27, 324, 305, 2.04 kg/m², and 4300 kg/ha, respectively, during 2018-19, and 104 cm, 26, 312, 289, 2.04 kg/m², and 4500 kg/ha, respectively, during 2019-20.

The difference in plant height between the two methods could be attributed to the densely populated plants in the conventional transplanting method, which limited their vertical growth. Variations in yield and yield attributing characteristics may be due to seedling damage during uprooting in the nursery beds of the conventional transplanting method. This difference is well explained by Maiti and Bhattacharya (2011) [1] and Rasool *et al.*, (2013) [3], who reported that planting fewer seedlings per hill results in healthier leaves and tillers, ultimately leading to higher grain yield. The increased number of tillers and higher yields in direct seeding may also be attributed to the proper row-to-row and plant-to-plant spacing compared to conventional manual transplanting.

Economic analysis of both methods of transplanting demonstrates that the cost of cultivating through manual transplanting (Rs. 40,985.00) exceeded that of direct seeding (Rs. 31,585.00). The gross return for manual transplanting and direct seeding was Rs. 84,000.00 and Rs. 93,000.00, respectively. Additionally, the net return for direct seeding (Rs. 61,415.00) surpassed that of manual transplanting (Rs. 43,015.00). A benefit-cost ratio of 2.94 was observed for direct seeding, while manual transplanting yielded a ratio of 2.05. Therefore, it can be concluded that direct seeding of rice is more profitable than conventional manual transplanting and has the potential to enhance farmers' economic prosperity.

Table 1: Cost of cultivation of conventional manual transplanting and direct seeding (Rs/ha)

S. No.	Operations	Manual transplanting	Direct seeding
Nursery			
1	Nursery bed preparation	1000	
2	Seeds	2000	2000
Main field			
3	Land preparation	7550	7550
4	Fertilizers (Basal+ Top dressing)	6435	6435
5	Transplanting		Sowing
Labour cost		5500	1250
6	**Weeding**		
Labour cost		5500	1000
Fuel for power weeder			850
7	Plant protection	2000	1500
8	Harvesting	6750	6750
9	Carrying	1750	1750
10	Threshing	2500	2500
Total		40985	31585

Table 2: Yield and yield attributing characters of demonstrated variety (Ranjit-sub 1) and farmer's variety (Mahsuri) during 2018-19 and 2019-20 Variety: Ranjit- sub 1 (Direct seeded)

Sl. No	2018-19						2019-20					
	Plant height (cm)	Plant /m²	Tille r/m²	Panicle/m²	Straw yield(kg/m²)	Grain yield(kg/ha)	Plant height (cm)	Plan t/m²	Tiller/m²	Panicle/m²	Straw yield(kg/m²)	Grain yield(kg/ha)
1.	119	30	390	370	2.3	5200	118	28	392	375	2.18	5025

Table 3: Variety: Mahsuri (Farmer's practice, transplanted)

Sl. No	2018-19						2019-20					
	Plant height (cm)	Plant /m²	Tiller/ m²	Panicle/m²	Straw yield(kg/m²)	Grain yield(kg/ha)	Plant height (cm)	Plant/m²	Tiller/ m²	Panicle/m²	Straw yield(kg/m²)	Grain yield(kg/ha)
1.	105	27	324	305	2.04	4300	104	26	312	289	2.04	4500

Table 4: Economic analysis of conventional manual transplanting and direct seeding during 2018-19 and 2019-20

Manual transplanting				Direct seeding			
Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C
40985	56q x 1500=84000	43015	2.05	31585	62q x 1500=93000	61415	2.94

4. Conclusion

Based on the results and discussion, it is evident that direct seeding of rice offers several advantages over conventional manual transplanting. The cost analysis showed that direct seeding incurred lower expenses in terms of nursery bed preparation, labour charges for sowing and weeding, as well as plant protection costs. This reduction in costs can be attributed to the use of mechanical paddy transplanters and power weeders, as well as the proper spacing maintained in direct seeding. Furthermore, the study revealed significant differences in plant height, number of plants, number of tillers, number of panicles, straw yield, and grain yield between direct-seeded plots using the Ranjit-sub1 variety and the farmers' practice plots using the Mahsuri variety.

Direct seeding resulted in taller plants, more plants per square meter, more tillers, more panicles, higher straw yield, and higher grain yield compared to manual transplanting. This can be attributed to the avoidance of seedling damage during uprooting in the nursery beds and the improved row-to-row and plant-to-plant spacing in direct seeding. From an economic standpoint, direct seeding proved to be more profitable. The cost of cultivating through direct seeding was lower compared to manual transplanting, resulting in higher net returns. The gross return and benefit-cost ratio were also higher for direct seeding, indicating its potential for enhancing farmers' economic prosperity.

In conclusion, the results strongly support the adoption of direct seeding as a superior method for cultivating rice. Its advantages include cost savings, improved yield performance, and increased profitability. Implementing direct seeding has the potential to contribute to sustainable agriculture, climate change resilience, and food security.

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