Adoption Pattern of Direct-Seeded Rice Systems in Three South Asian Countries during COVID-19 and Thereafter

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Abstract: COVID-19 has caused a deep economic impact on the lives of small and marginal farmers due to travel restrictions, market closures, and social distancing requirements. Due to COVID-induced labor scarcity and water shortage in India, direct-seeded rice (DSR) has emerged as a viable alternative to puddled transplanted rice (PTR). However, there was plenty of labor available in Pakistan and Bangladesh for rice cultivation during COVID-19 times. Therefore, both countries did not observe the shift from PTR to DSR. The cost of inputs, such as seed, fertilizer, pesticide, and fuel, was high due to a supply–demand conflict during the COVID-19 pandemic in three countries. Farmers faced weed problems and physical and/or economical non-availability of suitable machinery for DSR cultivation during the COVID-19 pandemic. In the later years of 2022 and 2023 (post-COVID), the area under DSR decreased by 88% in India, while it remained stagnant in Pakistan and Bangladesh.

Keywords: dry seeded rice; India; Bangladesh; Pakistan; coronavirus; pandemic; agriculture

1. Introduction

Coronaviruses (CoV), a large family of viruses, cause mild to severe illness [common cold, Middle East Respiratory Syndrome (MERS)-CoV, and Severe Acute Respiratory Syndrome (SARS)-CoV]. The World Health Organization (WHO) declared COVID-19, the new coronavirus disease, as a “pandemic” on 11 March 2020. Starting in 2020, COVID-19 caused havoc in life around the globe within the space of a few weeks. All industries were forced to close, and agriculture was no different. The pandemic significantly affected the physical, social, economic, and emotional well-being of all stakeholders of agricultural systems in South Asian countries (India, Pakistan, Nepal, Bangladesh, and Bhutan) [1]. In India, the first case of COVID-19 was reported in Kerala on 27 January 2020. By that time, more than 7500 cases were reported in 20 countries [2]. In Pakistan, the first case of COVID-19 was reported on 26 February 2020 [www.pakistantoday.com.pk, accessed on 4 March 2020]. Bangladesh reported the country’s first confirmed case of coronavirus disease (COVID-19) on 8 March 2020 [3].

On a global scale, the Food and Agriculture Organization (FAO) reported that COVID-19 affected the agricultural supply chains on two fronts, viz., the demand and supply for food [4]. COVID-19 lockdown caused a supply bullwhip effect (simultaneous fall in both demand and supply), and thus, the pandemic extended from being a health crisis into becoming a global economic crisis [5]. The restrictions on movement disrupted the...
supply chains, hampering the uninterrupted flow of inputs and outputs of agricultural activities [6,7]. When COVID-19 struck in March–April 2020 in South Asian countries (especially in north-west India), reverse labor migration and market closure adversely affected the harvesting of the winter (November–April) crops, especially wheat [8]. This created many threats to the sustainability of the agriculture sector, food, and nutritional security. Kumar et al. [9] argued that the disruptions in supply chains and reverse migration of laborers due to the COVID-19 crisis affected agriculture farms of all sizes. Ali and Khan [10] reported that perishable fresh fruit and vegetables with high water content faced a significant decline in wholesale prices during the lockdown. Mahajan and Tomar [11] reported that supply chain disruptions at the farm level resulted in a 10% reduction in the availability of vegetables, fruit, and edible oils at the online retail level. Similarly, Rajkhowa and Kornher [12] studied the impact of COVID-19 on retail and wholesale prices using fixed-effects panel regression models and found that prices increased for commodities with longer shelf-life such as pulses and processed items, while prices of vegetables such as onions and tomatoes declined substantially at the onset of the pandemic.

Cariappa et al. [6] observed that COVID-19 affected agriculture production and marketing through labor and logistic constraints. In the rice-wheat cropping system, the direct impact of COVID-19 incidence in north-western India was on wheat, as the crop harvest coincided with the lockdown [13]. Nevertheless, the country registered a record wheat procurement of 38.99 million tonnes. Rice is manually transplanted in puddled fields, and this puddled transplanted rice (PTR) system is labor-, water-, and energy-intensive. In the last decade, there was a gradual shift from PTR to direct-seeded rice (DSR) due to several advantages, such as better economics, greater resource use efficiency, early maturity, better soil structure, etc. [14,15]. McDonald et al. [16] indicated that reverse migration of agricultural migrants due to COVID-19 may delay rice transplanting in north India, which will cause productivity losses from later planting and can have serious implications on food security. The conditions during the COVID-19 pandemic led to the late sowing, transplanting, and harvesting of crops. The rice growers resorted to DSR amid COVID times as it requires less labor, water, and capital than PTR. DSR technology is an attractive option for reducing the environmental footprint of rice cultivation [17]. In this study, the adoption level of DSR was studied in three South Asian countries during COVID-19 times to understand the adoption pattern and underlying causes.

2. Materials and Methods

During the COVID-19 pandemic, agriculture was designated as an essential activity, and lockdown restrictions were relaxed for farmers and other related supply chains. Many researchers published papers on impact of COVID-19 on agriculture based on secondary data and result synthesis with statistical extrapolation or modeling techniques [5,10,11,13,16,18–21]. Some studies/policy papers hinted at the strategies to be adopted for fighting this pandemic and post-pandemic recovery options [6,9,22]. In this study, the area and production of rice in three South Asian countries were extracted from statistical records. The area under DSR during pre-COVID year (2018) was compared with COVID years (2020 and 2021). We surveyed farmers to look for plausible constraints and reasons for the varied adoption rates of DSR technology in post-COVID-19 times. Due to COVID restrictions, about 100 DSR farmers were selected randomly from the DSR niche in India, Bangladesh, and Pakistan in October 2020 using a questionnaire to investigate and understand the challenges faced by the farming community during the COVID-19 lockdown period. The interview data were statistically quantified into appropriate categories based on sample proportion, and econometric analysis of rankings was carried out by calculating the Rank Based Quotient (RBQ). The DSR area was also observed in post-COVID years (2022 and 2023) from the government records in these three South Asian countries.
3. Results

3.1. Adoption of Direct-Seeded Rice in Three South Asian Countries during COVID Times

DSR technology was adopted by farmers on 0.54 million hectares in 2020, which was a huge jump from 2019, when the DSR area was only about 23,300 hectares (Figure 1). In Pakistan, the area under DSR was 46,000 hectares (1.64%) in 2018, which reduced slightly to 33,650 hectares (1.2%) in 2020. In 2018–2019 (pre-COVID period), the DSR production area was only 7.9% of the total rice production areas, which was similar (8%) during the COVID-19 period in 2020–2021. In Bangladesh, the area under DSR remained stagnant throughout the study period from 2018 to 2023.

![Figure 1. Area under DSR in India, Bangladesh, and Pakistan before (2018), during (2020 and 2021) and after the COVID-19 (2022 and 2023) period.](image)

3.2. Adoption of Direct-Seeded Rice in Three South Asian Countries after COVID Times

In India, the area under DSR decreased post-COVID years to about 70,000 ha only (Figure 1). There was a significant jump and fall in the DSR area during 2020 and 2022, respectively. There was an increase in the DSR area by 194% during 2022 (after COVID) as compared to 2018 (before COVID). However, there was a decline in the area under DSR by 89% during 2022 (after COVID) as compared to 2021 (during COVID). Only an 11% increase was observed during 2021 than 2020. In Bangladesh, there was a 1–2% reduction in the DSR area from 2018 to 2023. In Pakistan, the area under DSR decreased by 26% and 52% during 2020 (COVID times) and 2023 (after COVID), respectively, as compared to 2018 (before COVID).

3.3. Issues/Challenges in DSR Adoption during COVID-19

**India:** Almost all respondents agreed that DSR is a highly location-specific technology (Figure 2). Around 60% of farmers reported that suitable rice drills were unavailable in the required quantity. Around 30–35% of farmers went for early sowing, which was much before the recommended time of 1–15 June for coarse rice. In north-western India (Punjab), about 90% of farmers rated weeds as the major problem (Figure 2). About 20% of farmers reported that unusual summer rains (2–3 spells) resulted in crust formation, hindering rice seedlings’ emergence. About 10% of farmers reported that there was some delay in the sale of rice grain due to the unavailability of labor.
Bangladesh: All farmers (100%) responded with a higher labor price (10–25%) during the COVID period, and 30% of farmers reported the timely unavailability of labor for transplanting. About 90% of farmers reported that the cost of inputs (e.g., seed, fertilizer, herbicide, pesticide, diesel, etc.) was comparatively higher during the COVID period due to their short supply, few retailers/shop options, and difficulty in transportation. Almost 60% of farmers complained about the timely or lack of availability of herbicide(s) required for DSR, resulting in difficulties in controlling grass weeds and requiring more laborers to control weeds. About 30% of farmers responded that they could not apply urea (as top-dress) and pesticide(s) on time due to reduced availability. Around 30% of farmers responded that they could not harvest the crop on time due to the non-availability of labor, and almost 100% of farmers paid higher costs for harvesting the crop during the COVID period. Due to strict lockdowns in some areas, 20–30% of farmers faced severe problems while transporting their produce to their homes as well as to the market. More than 50% of farmers paid higher costs for harvesting the crop during the COVID period.
farmers faced challenges in selling their rice because of a strict lockdown in the market and the absence of buyers (rice traders).

**Pakistan:** Most (98%) of the farmers responded that they had easy availability of labor with low labor prices (10–15% less). About 90% of farmers reported that they had access to machinery for sowing and tillage practices under lockdown conditions. Regarding the availability of farm inputs, 100% of farmers reported that the price of all inputs (seeds, herbicides, fertilizers, diesel, pesticides, etc.) was relatively higher (by 15–25%, personal experience) during the pandemic condition of COVID-19. Few farmers (20%) have also reported the problem of the short supply of inputs in retailers’ shops and transportation difficulties. About 10% of farmers have also reported that they face the problem of timely application of fertilizers and pesticides due to high prices and difficulty in transportation. About 90% of farmers reported that labor and/or harvester combines were available for harvesting; however, few farmers faced the problem of transportation to take produce from the field to the market. About 75% of farmers faced the problem of selling as there was a shortage of rice traders (buyers) during the strict lockdown.

4. Discussion

4.1. Rice Production in Three South Asian Countries

Global rice production is virtually unchanged during the COVID period from 2018 to 2021. India is the largest exporter and the second-biggest producer and consumer of rice after China. In India, the area under rice during 2020–2021 was 4% more (44.4 million hectares) than the area under rice during 2018–2019, i.e., the pre-COVID period [23]. India was the top rice exporter worth USD 7.35 billion and 7.98 billion in 2018 and 2020, respectively. Though manual transplanting in puddled fields (PTR) is the main planting technique, the scarcity of labor induced by COVID resulted in a jump in the DSR area (Figure 1). Therefore, Indian farmers were able to maintain the area and production levels of rice.

In Bangladesh, rice is grown year-round, with three distinct growing seasons known as pre-monsoon or *aus* rice (April–August), monsoon or *aman* rice (June–November), and winter or *boro* rice (December–May) covering 12, 44, and 44% of the total rice area, respectively [24]. The total rice production in Bangladesh was 36.4 and 39.6 million tonnes, respectively, in 2018–2019 (before COVID) and 2020–2021 (during the COVID period). Although rice production during the COVID period (2020) was around 3.0 million tonnes higher than in the pre-COVID period, Bangladesh imported more than 9.0 million tonnes of rice during the COVID years to feed the citizens who had returned from other countries due to reverse migration caused by COVID.

In Pakistan, an area of 3.04 million hectares was used to cultivate rice during 2020–2021, a 9.9% increase compared to the area during 2018–2019. The domestic price of Pakistani rice changed slightly to USD 365/ton during 2020–2021. Overall, the area and production of rice were found to be unchanged during the COVID-19 pandemic times in India, Pakistan, and Bangladesh.

4.2. Adoption of Direct-Seeded Rice in Three South Asian Countries during COVID Times

In South Asian countries, rice is mostly established under puddled conditions, followed by the transplanting of rice seedlings, which requires a huge amount of water and labor. Balwinder-Singh and team [18] raised the concerns that reverse migration and, thus, reductions in labor availability may jeopardize agricultural production and, consequently, national food security. Reverse migration is a term used when many workers across economic sectors return to their home regions from their workplaces. Technological options such as direct-seeded rice and staggered nursery transplanting may help address the challenges of labor scarcity, but a huge shift in policy and incentives for change is needed. The evaluation of four scenarios representing a range of plausible labor constraints on the timing of rice transplanting in Punjab and Haryana was made using a spatial ex ante modeling framework and a loss in the range of 9–21% for total rice-wheat system
productivity, which was equivalent to economic losses of USD 674 m to USD 1.48 billion was estimated [18]. Our study provided evidence that DSR helped in addressing labor scarcity issues and, thus, prevented huge losses (due to delay in transplanting) as estimated by Balwinder-Singh and team [18].

In Pakistan, the area under DSR was slightly reduced from 2018 to 2020 due to the non-availability of effective herbicide(s) to control grass weeds in DSR. In Pakistan, more laborers were available for the agriculture sector as industries were closed during lockdown situations, and rice transplanting faced no problems. In Bangladesh, DSR is cultivated in the *aus* and *aman* seasons and almost nil in the *boro* season. Rice production methods did not change much during the COVID-19 pandemic. PTR was the major production system, and DSR was practiced on less than 10% of its land (in some pockets only). The major driver of DSR practices in these pocketed areas was mainly water scarcity. Farmers practiced DSR (manual broadcasting after dry tillage) in some areas during the *aus* season, but the yield obtained by farmers was very low and not profitable.

In India, the agriculture and allied sector is a source of livelihood for as much as 54.6% of India’s workforce, and agriculture contributes 16.1% to the Gross Domestic Product. The COVID-19 crisis resulted in restrictions (partial or complete lockdown) on inter- and intra-state transports/movements within each country that disrupted the supply and/or value chains of perishable food commodities and spiked their prices. India’s food supply chain, which initially dropped by 69% (in the three weeks following the lockdown), recovered immediately (after six weeks of lockdown) [21]. This suggested that strict lockdown measures at the onset of pandemics did not cause long-term economic damage. In India, both “agriculture” and “markets” are state subjects and states play a crucial role in maintaining agri-food markets and supply chains during COVID-19 [19]. The favorable policies of state governments in northwest India aided in the adoption of DSR technology during this pandemic. DSR technology is being promoted as a labor-saving and water-conservation practice in the north-western Indian plains. The labor scarcity coupled with high wage rates during COVID-19 (over doubled from USD 70/ha during pre-COVID times to USD 150/ha during the COVID times) helped significantly for the wider adoption of DSR technology in the Indian subcontinent. To cope with the labor problem during COVID, the state governments incentivized DSR sowing by giving seed and sowing machinery at subsidized rates (at 40–50% subsidy). The state governments of Punjab and Haryana in India provided big rice farmers, cooperative societies, and custom hiring centers with seeding machines at subsidized rates.

4.3. Adoption of Direct-Seeded Rice in Three South Asian Countries after COVID Times

In India, the areas under DSR decreased in post-COVID years due to more availability of cheap labor for manual transplanting. However, the government announced incentives in the form of Indian Rupees 3750/ha (USD 80) for DSR. Even so, the area under DSR was reduced drastically in northwest India, indicating that the large jump in DSR adoption during COVID times was mainly due to labor scarcity. In India, adoption of DSR amid COVID-19 was primarily concentrated in north-western states, especially Punjab, followed by Haryana and western Uttar Pradesh. In north-western India, migrant laborers from Bihar, Uttarakhand, and eastern Uttar Pradesh are regularly employed. An assessment by the Punjab government (India) put the total number of migrant workers in the state’s agricultural sector at about 700,000 [25]. In Bangladesh, the DSR areas changed very little from year to year based on irrigation water/rainfall availability. Since the major driver for DSR adoption in Bangladesh was the paucity of irrigation water, COVID-19 did not affect rice production practices before, during, and after the COVID period. Similarly, the area under DSR was reduced post-COVID in Pakistan as well.

4.4. Issues/Challenges in DSR Adoption during COVID-19

Farmers who were adopting this technology for the first time experienced many technological challenges. Due to COVID-19 restrictions, it was hard to educate, disseminate
and train the full package of practices of DSR through mass gatherings (farmer fairs), demonstrations, and training. In this difficult time for farmers, SAUs and state agriculture departments used IT tools and social media to create awareness and training for farmers for the adoption of DSR technology. In India, digital services (e.g., WhatsApp, short message services, YouTube videos, Facebook Live, etc.) have been valuable in connecting farming communities and sharing vital information without physical gatherings. Farmers broadcasted seeds in dry or moist soil that required a higher seed rate. Farmers cultivating long-duration coarse varieties started early sowing of DSR (around mid-May). Early sowing in May resulted in more water use for the cultivation of rice, thus escalating the underground water woes of that region. The impact of the lockdown on market arrivals and price margin was estimated with an interrupted time series analysis model approach, and results revealed that wholesale and retail prices for wheat and rice decreased significantly during the lockdown period of 2020 and 2021 [26].

Farmers faced difficulty in controlling grasses and sedges in DSR fields. Due to COVID-19-related restrictions, herbicides were either unavailable or the supply was inadequate (short supply), resulting in higher prices. About 30% of farmers sprayed either ineffective post-emergence herbicides or at a later weed growth stage, which resulted in poor weed control. About 40% of farmers reported the problem of “volunteer rice” and “weedy rice” in DSR fields. Additionally, the electricity supply was erratic in the May-June months, leading to an extra investment (USD 16–25) by the farmers on diesel (to pump out underground water) for irrigating their DSR. About 40% of farmers continued with the flood (surface) irrigation and ponding of water in DSR fields as they do in PTR fields, resulting in more water use. In some areas, enthusiastic farmers planted DSR in light sandy soils but were forced to plow up fields due to severe chlorosis caused by iron deficiency. About 10% of farmers reported rodents as a major problem in DSR fields.

In Bangladesh, the engagement of family members in farming was more during the COVID period than in the pre-COVID times, as educational institutes were mostly closed. Farmers did not face any irrigation and electricity problems during the COVID period in DSR cultivation. Most farmers responded that their DSR fields were near their homes and that there was no problem monitoring them. The transport cost was almost double that in the pre-COVID period. In some regions, rice traders come from other areas, and during the COVID lockdown, they were not able to come. More than 50% of farmers received a comparatively lower price for the rice produced in the market than the previous year. Due to higher costs of labor and inputs, higher transportation costs, and less or similar prices of rice, more than 80% of farmers reported their profit margin was less than in the pre-COVID period. Burning rice residue is uncommon in Bangladesh, and rice straw is used as cattle feed.

In Pakistan, a positive social change was observed during COVID times as family labor was more employed in their fields. The easy and ample availability of labor was mainly due to the lockdown of the small, medium, and large industries in cities, which caused many people to lose their jobs and eventually return to their homes in rural areas. No electricity or irrigation problems were reported in DSR cultivation under pandemic conditions. The short supply of inputs lasted through the start of the lockdown (i.e., April 2020) for a couple of weeks, and then the government lifted the lockdown conditions on agricultural commodities and inputs. Weeds were a problem due to the non-availability of particular herbicides being used for weed control in DSR fields. Many post-emergence herbicides, such as fenoxaprop, are not registered and available in Pakistan. A price hike in paddy rice was observed during lockdown conditions, but most of the farmers received a price similar to pre-COVID conditions.

5. Conclusions
Agriculture is the mainstay of the economy in India, Bangladesh, and Pakistan. In these countries, a survey was conducted to understand the impact of COVID-19 on agronomic and cultural practices used by rice farmers, production constraints, and the economics
of DSR cultivation. The area, production, and export of rice in these countries were unchanged during COVID-19 times. There was a COVID-induced labor shortage (due to reverse migration) in north-western India, which boosted the adoption of DSR technology. Plenty of labor was available for rice cultivation in Bangladesh and Pakistan; therefore, the area under DSR in these two countries did not increase during COVID times. Rice farming inputs were in short supply and available at a 15–25% higher price. Due to the COVID-19 pandemic, farmers learned to use the resources efficiently and resorted back to cooperative farming. Considering futuristic drivers of change in the rice industry (labor, water scarcity, availability of suitable machinery for seeding, herbicide options, and awareness through social media), the area under DSR may increase in South Asia.

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