International Journal of Scientific Research & Engineering Trends
Volume 10, Issue 5, Sept-Oct-2024, ISSN (Online): 2395-566X

A Review on Direct Seeded Rice: A Sustainable Approach to Paddy Cultivation

Jagdeep Singh, Assistant Professor Dr. Gurshaminder Singh
UIAS, Chandigarh University, Gharuan, Mohali, Punjab, India

Abstract- Agriculture is crucial for the Indian economy. Rice is a staple crop to more than half of world population. Conventional transplanted rice production faces issues like lowering water tables, lower productivity, methane emissions, soil health deterioration, and labour scarcity. Puddling, a crucial step in wetland rice production, can improve transplanting and weed management but can also cause soil conditions that are unfavourable for post-rice crops. Puddled transplanted rice is energy-intensive and contributes to climate change by emitting methane and nitrous oxide. Direct seeded rice (DSR) technologies can minimize environmental impact and increase productivity. DSR was introduced in 2009-10 to address labour constraints, rising labour prices, and a diminishing groundwater table in Punjab. With agricultural water requirements expected to increase by 20% by 2050, DSR requires about 50% less water under Indian conditions. This review article studies the condition of current rice production practices, the major constrains and DSR, its advantages along with agronomy as substitute of current TPR method.

Index Terms-Transplanting, TPR, DSR, Productivity

I. INTRODUCTION

Agriculture, being the backbone of Indian economy is the driver of our economy. To cope with increasing population, we need to increase foodgrains production by 3 million tones every year. Rice is the staple crop in the world and there are several issues such as lowering water table, lower productivity, methane emissions, deteriorating soil health and labor scarcity during peak requirement hours are associated with conventional transplanted rice (Tyagi et al, 2020). Puddling is a crucial step in wetland rice production because it allows for easier transplanting, weed management, and lowers water and nutrient loss through percolation. Aside from these benefits, puddling causes physical conditions in the soil that are unfavourable to post-rice crops. Wet tillage and submerged circumstances can significantly alter the physical properties of rice soil.

These effects can persist for a short or long time (Kalita et al 2020). Puddled transplanted rice production systems are energy and cost demanding, resulting in a less lucrative system. Puddled transplanted rice is an energy-intensive crop establishment method for rice that has been shown to erode soil systems and have a negative impact on subsequent winter crops. (Jat et al 2022). Rice cultivation contributes to global climate change by emitting methane and nitrous oxide, and also suffers the repercussions. Methane is produced in soil by the metabolic activities of a tiny but very specific bacterial group known as methanogens. Microbial activity increases in submerged, anaerobic conditions found in wetland rice fields, where oxygen transfer is limited (Pathak et al 2011, Pathak et al 2010). As a result, there is an urgent need to identify appropriate crop establishment methods, particularly for rice production systems, in order to mitigate the negative effects of climate change while increasing productivity and profitability. Direct seeded rice (DSR) technologies have the ability to significantly minimise the environmental footprint while increasing productivity. (Jat et al 2022).

Farmers in Punjab have been forced to discover an alternative to resource-intensive puddled transplanted rice (PTR) due to labour constraint, rising labour prices, and a diminishing groundwater table. Dry-seeded rice (DSR) was introduced in 2009-10 to solve these issues (Bhullar et al 2018). DSR is suitable approach to meet the problems arising due to PTR. It is expected that agricultural water requirement is going to increase by 20% in 2050, with limited resources, we need to adopt methods which require less water such as DSR. It is claimed that DSR requires about 50% less water under Indian conditions.

The conditions in DSR are almost aerobic, so it significantly reduces methane emissions from paddy fields. Due to migration of rural population towards cities has created gap between demand and supply of agricultural labour for operations such as transplanting, DSR with more extent of mechanization can solve this problem along with increasing productivity at reduced costs (Sandhu et al 2021).

II. CURRENT SCENARIO OF PADDY CULTIVATION

Oryza sativa L. is the primary food crop for around 3.5 billion people worldwide, with the majority grown in Asia. It is cultivated 2700 feet above MSL. Rice is currently grown in over 114 nations, with more than 50 countries producing 0.1 million tonnes or more each year. Currently, it is the staple food of about 3 billion people, accounting for roughly half of the global population (Singh 2020). On a global scale, rice covers 163.5 million hectares, with an annual production of 758.9 million tonnes and a productivity of 4641.5 kg per hectare. In India, it is grown on around 42.5 million hectares with a total production of 105.5 million tonnes and a productivity of 3632.9 kg/ha. The impending water crisis, the water-intensive character of traditionally grown rice, and rising labour costs have prompted a quest for new management strategies to boost water productivity, system sustainability, and profitability (Chaudhary et al 2023, Joshi et al 2013). Methane (CH_4) is the second most potent greenhouse gas and plays a key part in atmospheric chemistry as a short-lived climatic force. Atmospheric CH_4 concentrations grew from 700 ppb in 1900 to 1880 ppb in 2020, primarily due to increased emissions from human activities such as fossil fuel mining, waste management, and agriculture (Ito et al 2022). Global warming is a serious issue that threatens human life on Earth. Increased greenhouse gas levels in the atmosphere are a primary contributor to global warming. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are classified as important greenhouse gases. Rice fields are a major source of agricultural methane (CH_4) emissions, accounting for 20-40 Tg CH_4 per year and 52% of total global emissions (Sun et al., 2016) [16]. Rice cultivation produces large greenhouse gas emissions, including methane (CH_4) and nitrous oxide (N_2O). Methane emissions from paddy fields account for 29% of total CH_4. N_2O emissions from agricultural land account for 52% of total anthropogenic N_2O. Thus, greenhouse gas emissions from rice paddy fields are regarded as one of the most significant emission sources. Methane emissions from paddy fields are highest when the field is inundated and decrease when the field is drained. Nitrous oxide emissions from paddy fields are minimal when flooded, but significantly higher when drained (Ramesh & Ritika 2020, Sun et al 2016). According to significant researches on Punjab's water resources, the state has a water shortage, which has resulted due to over-exploitation of groundwater as opposed to recharging. The total available water is calculated at 3.82-million-hectare meters (mHaM), with 3.12 mHaM of acceptable quality and 0.24 mHaM of somewhat fit water.1 These fall short by 1.54 mHaM (15.4 km^3) of the normative need of 4.90 mHaM (Singh 2011, Prihar et al 1990). These concerns highlight the necessity for an alternative crop establishment approach. Direct-seeded rice (DSR) is gaining popularity due to its lower input requirements compared to PTR (Chaudhary et al 2023).

III. DIRECT SEEDED RICE

Rice (Oryza sativa L.) is a staple food for over half of the world's population. Manual puddled transplanted rice (PTR) is still the most common method of rice establishment. However, because to decreasing water tables, increasing water shortages, the water, labour, and energy-intensive nature of PTR, high labour wages, the negative consequences of puddling on soil health and subsequent crops, and significant methane emissions, this production system is becoming less economically viable(Ladha et al 2009). Puddling and transplanting consume 30% of the total water requirements of rice, and require much energy and labor (Xu et al 2023). These concerns highlight the necessity for an alternative crop establishment approach. The direct-seeded rice (DSR) technique is gaining popularity due to its lower input need than PTR. It involves spreading pre-germinated seeds in puddled soil (wet-DSR), standing water (water seeding), or dry seeding on a prepared seedbed (dry DSR). DSR uses less water and labour (12-35%), emits less methane (10-90%), improves soil physical qualities, demands less drudgery and production costs (US$9-125 per hectare), and delivers equivalent results. Improved early maturity and high-yielding cultivars, as well as effective nutrition, weed, and resource management techniques, pushed farmers to adopt DSR culture(Chaudhary et al 2023).

Direct seeding of rice is mainly done by 3 methods viz, Wet DSR, Dry DSR and Water seeding. A) Wet seeding involves putting pre-germinated seed in standing water or puddled soil. Pre-germinated seeds (radicle 1-3 mm) are spread or placed in rows on wet and puddled soil. When pre-germinated seeds are scattered on the surface of puddled soil, the seed environment becomes aerobic, resulting in aerobic wet-DSR (surface). A drum seeder can be used for this purpose. When pre-germinated seeds are drilled into puddled soil, the seed environment becomes anaerobic, a condition known as anaerobic wet-DSR (subsurface). B) In Dry DSR, seeds are sown or drilled in dry and un-puddled seed bed by following methods like zero tillage, minimum tillage etc. The growing environment is basically aerobic. It is manly done to reduce labour cost and it is a quiet popular method worldwide. C) Water seeding is spread over of seeds over standing water in fields. Water seeding is widely used in the United States to minimize severe damage caused by noxious weeds such as weedy rice. Aerial water seeding is the most frequent approach for suppressing difficult-to-control weeds, such as wild rice, in California (USA), Australia, and Europe(Chaudhary et al 2023, Singh et al 2020). Labour costs account for more than half of the entire cost of rice production. Hired and operator, family, and exchange (OFE) labour accounted for over 53% of total production costs in

2020, owing to high level labour requirements and rising agricultural wage prices. Rising wage rates have led to a shift from TPR to DSR among rice growers in Asia. More farmers are expected to switch to DSR as labour becomes scarcer, irrigation water availability drops, and crop intensification and diversification become more important in achieving food and nutrition security. Other reasons for acceptance include labour savings for increased revenue, the availability of high-yielding, short-duration rice varieties, and low-cost chemical weed control techniques(Bautista et al 2023).

Adoption of DSR can help in many ways such as it requires lesser water to cultivate as DSR paddy requires about 150mm irrigation water or rainfall for crop establishment as compared to 450mm for the same in TPR. Moreover, DSR has deeper root system which utilises water more efficiently. Labour requirement and availability is a big issue in conventional TPR, which includes laborious activities such as nursery raising, uprooting and transplanting, which is greatly reduced in Direct Seeded Rice and thus results in less cost and eventually more profits to farmer. Along with income, DSR eliminated the cost of puddling which deteriorates soil structure and impacts soil fertility. It is evident that rice cultivation is the major contributor of greenhouse gases like methane and nitrous oxides. The metabolic activities of methane producing bacteria enhances in the submerged anaerobic conditions which is limited to a great extent in DSR (Singh et al 2020).

Despite its advantages over TPR, DSR faces two key biological restrictions. The first is non-uniform seedling stand density (SSD or seedling emergence performance). In TPR culture, seeds germinate and seedlings grow under controlled settings in nurseries, whereas in DSR cultivation, seeds and seedlings are subjected to adverse environmental factors during germination and emergence, which can result in non-uniform SSD. A high sowing rate is typically recommended to maintain consistent Seedling Stand Density (SSD), however this wastes seeds, resulting in high population density and low quality. The second important barrier is heavy weed infestation (Xu et al 2023). Weed management strategies in direct seeded rice are determined by the critical period for weed control, the weed flora, and the method used. To accomplish long-term and sustainable weed management in DSR, the integration of several weed management strategies, such as integrated weed management (IWM), is required. The simultaneous development of competing weeds, the lack of water to suppress the weeds at the period of seedling emergence, and the predominance of difficult-to-control weeds are the primary causes of the significant weed infestation in DSR. Weeds will have a severe effect on output, quality, and production costs due to competition for numerous growth nutrients (Singh et al 2020). Weeds dominate crops due to their hardy nature and they dominate seedling habitat and diminish yield potential(Raj & Syriac 2017). DSR possesses advantages over TPR, such as saving irrigation water, labour, energy, and time, reducing greenhouse gas emissions, and improving crop growth. However, traditional puddled transplanting systems (PTR) use a large amount of irrigation water for puddling, which breaks capillary pores, destroys soil aggregates, and causes hard pan formation, which can hinder crop establishment and growth (Tyagi et al, 2020).

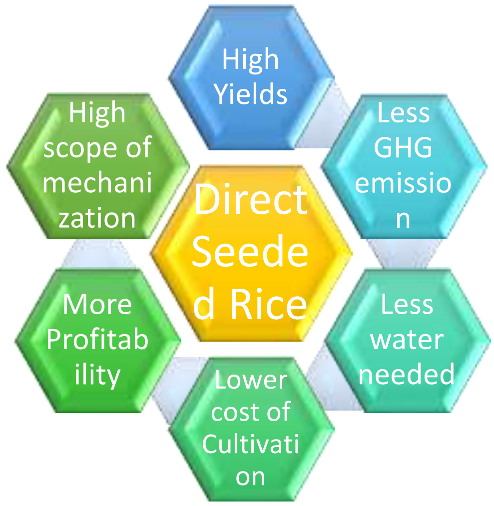

Figure 1: DSR Advantages

IV. CONSTRAINS IN CONVENTIONAL TRANSPLANTED PUDDLED RICE (TPR)

1. High Water Requirements

Rice is principal diet component for billions of people worldwide. Water required to produce 1 kg of rice is much higher than other crops (Singh et al 2020). Conventional TPR requires 3000-5000 litres of water to produce a kilogram of rice. It is estimated that agriculture utilizes 70-80% of fresh water and paddy cultivation alone contributes 85% of the total freshwater usage. The depleting water table in paddy growing belts is a matter of concern(Pathak et al 2011). TPR requires two to three folds more water than any other cereal crop. In Asia, it accounts for 50% of total irrigation water. The increasing population and overutilization of freshwater resources for irrigation has significantly reduced the Per-capita availability of water to 1611m3 in 2015 from 5831m3 in 1951 and it is expected to further drop to low levels of 1292m3 by 2050 (Chaudhary et al 2023). Over the years, depleting water table in Punjab, one of the major Rice growing state in India has been a matter of great concern. The expansion of rice fields, which are the main crop that uses a lot of water, is one of the main issues that are frequently raised. In 1980, there were less than 0.4 million hectares (mha) of rice farmland; by 2010, that number had risen to 2.8 mha. The rice belt in the state's centre is entirely irrigated, mostly with groundwater drawn from withdrawals and some with the use of canals. The South West Punjab, where the groundwater is ill-suited for agriculture, has received the canal water from this sub-region over time. As a result, the water table in central Punjab had dropped significantly, from 4-5 meters in 1973 to more than 14 meters in 2005 (Singh 2011).

2. Deteriorating Soil Health

Puddling is a crucial step in wetland rice production because it allows for easier transplanting, weed management, and lowers water and nutrient loss through percolation. Puddling is the mechanical manipulation of the soil within a limited range of moisture contents above and below field capacity (0.3 bars) that destroys the aggregated condition of the soil, causing the aggregates to lose their identity and the soil to become a structurally more or less homogenous mass of fine particles. The puddled soil becomes dense with degraded structure, containing large number of single-grain structures and becomes hard and cloggy when dried.

However, puddling causes unfavourable physical conditions in the soil that are negative for post-rice crops. The puddling index (%) of rice soils increased substantially when farmers used mechanical puddling devices. Regardless of the tillage treatments used for puddled rice cultivation, surface layers had larger bulk densities (Mg/m3) than subsurface layers. (Kalita et al 2020). Puddling the soil has its advantages for rice cultivation. It forms an impervious covering that reduces water percolation losses, promotes easy seedling establishment, eliminates weeds, and generates anaerobic conditions to improve nutrient availability. However, frequent puddling degrades soil aggregates, breaks capillary pores, reduces permeability in subsurface layers, and creates hard pan, all of which are unfavourable to the establishment and growth of the following crop.

Figure 2: Puddling

Furthermore, puddling and transplanting require a huge amount of water (3000-5000 L water to produce 1 kg rice] and human labour, both of which are increasingly scarce and expensive on a daily 2023). In the post-green revolution period, questions about soil health and long-term sustainability are emerging throughout tropical rice ecosystems as soil fertility declines. Experimental patterns of yield decline/stagnation in South Asia were related to soil problems in rice-rice or rice-wheat systems, namely a decline in soil carbon (SOC) as well as other macro- and micronutrients, a high accumulation of Fe^{2+}, phenolic compounds, and sulphides. The puddling process negatively impacts soil health by causing compaction, reduced permeability, and poor aggregate stability. DSR can help restore soil structure that would otherwise be destroyed by puddling (Singh et al 2020).

3. Methane Emissions

Conventional puddled transplanted rice is a significant contributor to greenhouse gas emissions, specifically methane, which is responsible for climate change and global warming. According to the 2007 Intergovernmental Panel on Climate Change, by the end of the twenty-first century, temperatures would have increased by 1.1 to 6.4°C (Pathak et al 2011).

Methane and nitrous oxide emissions from rice farming are rapidly contributing to global climate change. The metabolic activity of various methane-producing bacterial strains improves proportionally in submerged or anaerobic environments often found in wetland paddy fields (Singh et al 2020). Various studies on methane emissions footprints in anaerobic rice and ratoon rice and found that Methane (CH_4) emissions were substantially higher in transplanted paddy as compared to ratoon crop, and emissions peaked at peak transplanting when the flooded water caused anaerobic conditions (Song et al 2021). Scientists at Tamil Nadu Rice Research Institute collected gas samples from rice fields under wet seeded, transplanted and SRI method using static chambers and data revealed that methane emission peaked at maximum tillering stage and declined thereafter. Whereas, in drip irrigation more CO_2 emissions were there at tillering stage and declined there after (Ramesh & Ritika 2020).

4. Labour Shortage

Conventional TPR requires a lot of labour. However, there is a labour shortage in Indian farming. The physical drudgery of farming, migration of labour to cities in search of an urbanised lifestyle, low wages and temporary employment in agriculture, preference for non-agricultural work, and participation in social welfare programs like The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), 2005, are the main causes of the scarcity. The problem has gotten worse because to curbs relating to the Covid-19 epidemic. In addition, labour scarcity is site- and season-specific due to the mismatch between supply and demand at the appropriate time and location. The labour scarcity has significantly increased the labour wages which is making conventional paddy cultivation uneconomical (Chaudhary et al 2023). Crop establishment alone requires 25% of total labour requirement hence, it created extensive

International Journal of Scientific Research & Engineering Trends
Volume 10, Issue 5, Sept-Oct-2024, ISSN (Online): 2395-566X

demands within a short period of time, making the condition severe (Bautista et al 2023).

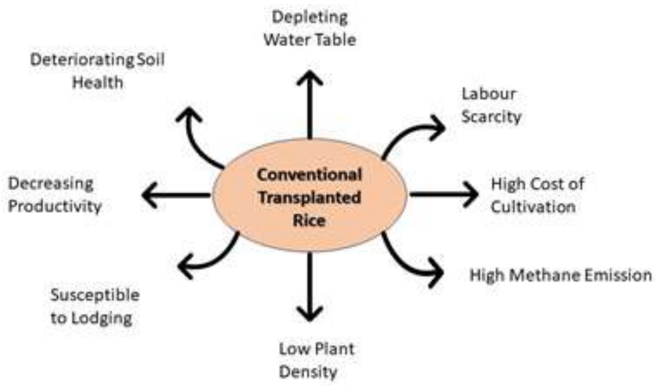

Figure 3: Constrains in Conventional Transplanted Rice

V. AGRONOMIC DRIVERS OF DSR

1. What is DSR?

Direct sowing is the oldest known way of rice establishment. It was popular prior to the 1950s, but puddled transplanting progressively superseded it. Direct seeding can be done in three methods, which vary over time due to technical advancements and need for more resource-efficient practices. Direct seeding methods are defined by land preparation, seed bed quality, sowing method, and seed environment (aerobic or anaerobic). These methods include dry, wet, and water seeding (Grigg 1974 Chaudhary et al 2023). Direct seeding reduces water usage by approximately 30% (0.9 million litres per acre) since it avoids seedling raising in a nursery, puddling, transplanting under puddled soil, and retaining 4-5 inches of water at the during and after transplanting of seedlings. On the contrary, direct seeding (both wet and dry) eliminates nursery raising, seedling uprooting, puddling, and transferring, lowering labour requirements. Avoiding transplant shock allows DSR to mature earlier than TPR, resulting in faster physiological maturity and reduced vulnerability to late-season water scarcity.

2. More Production

Studies have found that DSR yields are comparable to Conservation Tillage-TPR yields. Some surveys imply that good management techniques lead to similar or even better DSR yields because of improved yield attributes such as a greater number of panicles, higher grain weight[test weight], lower percentage of sterility and others (Marasini et al 2016). For improving yields of rice, a comparison study was conducted between the direct seeded rice crop establishment method and the mechanical transplanting method. The DSR option resulted in much higher rice productivity (+10%) than mechanically transplanted rice. In this scenario, the DSR option outperformed the mechanically transplanted rice in terms of growth parameters, effective tillers (+37%), panicle length (+8%), number of grains per panicle (+21%), and 1000-grain weight (+2%) (Jat et al 2022). During various trials conducted at Punjab Agricultural University DSR performed better in terms of yield, productivity and yield attributes such as Dry matter accumulation, Leaf Area Index(LAI), produced a greater number of productive tillers and had better water utilizing efficiency, which clearly indicates about the yield potential of Direct Seeded Rice (Gill et al 2006).

Figure 4: More Number of Tillers in DSR(1.) as compared to exact same variety in TPR(2.)

3. Efficient Utilization of Water

TPR requires two to three times more water than any other cereal crop. In Asia, it accounts for 50% of total irrigation water. The increasing population and overutilization of freshwater resources for irrigation has significantly reduced the Per-capita availability of water to 1611m3 in 2015 from 5831m3 in 1951 and it is expected to further drop to low levels of 1292m3 by 2050. The adoption of DSR can help to bring down the requirement of water and reduce pressure on natural resource base. Almost all sections of the Indo-Gangetic Plains typically observe pre-monsoon rain between mid-May and mid-June. If appropriate rains are received, this can be used to kill the first flush of weeds with non-selective herbicides (glyphosate and paraquat) in a stale seed bed method, as well as to plant direct seeding rice crops using a zero till machine. If there is no rain from mid-May to mid-June, surface irrigation should be done before planting. In fact, no irrigation is necessary between seedling and crop emergence, and the soil should be moist but not saturated from sowing until emergence. One or two irrigations are required between crop emergence and the beginning of the monsoon season. There is no need for additional irrigation after the rains begin until a dry period occurs. During dry spells, irrigations can be life-saving, especially during important growth stages like as tillering, panicle initiation, blooming, milking, and grain filling. Many researches have examined DSR's potential as an alternative for PTR. For

International Journal of Scientific Research & Engineering Trends
Volume 10, Issue 5, Sept-Oct-2024, ISSN (Online): 2395-566X

example, in on-farm testing, wet-DSR saved an average of 67-104 mm (11-18%) irrigation water compared to CT-PTR while maintaining the same irrigation application parameters for both rice establishment procedures. DSR has a higher adaptability to climate change than PTR since it uses less water and is more tolerant to water stress. Climate change is predicted to increase rainfall variability, as well as the risk of drought and water scarcity in the future. Dry-DSR with minimal or zero tillage expands the technology's potential by saving labour and addressing water scarcity. (Chaudhary et al 2023, Chaudhary et al 2015, Gill et al 2011, Pathak et al 2011).

Figure 5: High Water requirement in Transplanted rice(1.) as compared to less water requirement in Direct seeded rice (2.)

4. Addressing Labour Shortage

Manual transplanting is the traditional way of establishing rice crops around the world. As a result, crop establishing accounts for more than 25% of total labour expenses, increasing rice production costs. The implementation of DSR resulted in less labour and cheaper crop establishment costs, as well as increased labour productivity. However, its main disadvantages compared to TPR were poorer yield in some cases, greater seed and pesticide expenditures. Despite this, the partial budget analysis revealed that switching to DSR resulted in added income, particularly in rainfed areas and during the dry season, as labour savings offset for the increased seed and herbicide costs and yield loss (Bautista et al 2023). Dawe observed that the labour required for agricultural operations decreased at a rate of 0.1-0.4% each year, with an average of 0.2%. Because of severe labour scarcity, labour wages have been increasing dramatically in recent years. This has rendered the CT-PTR system uneconomical. All of these considerations emphasize the necessity for alternative techniques such as DSR. DSR requires less labour because it does not involve raising nurseries, uprooting seedlings, puddling, or transplanting. DSR requires roughly 5 person-days per hectare, as opposed to transplanting, which requires 25-50 person-days (Dawe 2005, Balasubramanian et al 2001).

5. Environmentally Feasible

Direct Seeded Rice (DSR) systems have been proposed as a sustainable strategy for rice (Oryza sativa L.) production and resilience in the face of unfavourable climatic conditions. Adoption of DSR solutions without increasing rice nursery increases rice productivity and saves time. It was also found that DSR plots were more tolerant to lodging as compared to mechanically transplanted and conventional rice (Jat et al 2022). Labour savings ranged from an average of 24 in manual transplanting to 2 in direct seeded rice (DSR) and 1 in drum seeded rice. DSR seeded rice took the shortest time to mature, 136.5 days, compared to 142.5 days for manual transplanting and 138 days with drum seeder. The B:C ratio was best in DSR in the zero till condition (2.29) when compared to hand puddled transplanted rice (2.06) and drum seeder (2.18). The study found that the traditional approach of puddled transplanting might be substituted with zero till DSR to boost the BC ratio (Kumar et al 2015).

VI. HOW DSR?

1. Land Preparation

Land Levelling is the first and most crucial phase in DSR adaptation. Before direct rice sowing, the land should be levelled using a laser land leveller. Laser field levelling technology has the ability to save water, develop uniform crops, improve nutrient efficiency, improve environmental quality, and increase grain yields. A fine seedbed should be prepared before sowing (Kakraliya et al 2016, Singh et al 2020).

2. Seed Treatment

Seed Priming is one of the quickest and most practical ways to combat the negative impacts of drought stress. Insufficient soil moisture can be a key obstacle to faster and better crop establishment because DSR crops are sown at a shallow depth (<2 cm) before the monsoon rains arrive. By allowing seeds to be partially hydrated to the point where germination-enhancing metabolic activities are enhanced, but without reaching the irreversible stage of radical emergence, a pre-sowing hydration approach known as "seed priming" is used. Places where seed-borne diseases are an issue, treating seeds with the proper fungicides is advised to control conditions including loose smut, false smut, root rot, collar rot, and stem rot. To do this, a known quantity of seed is soaked for 24 hours in water and fungicide solution (either carbendazim-Bavistin at 2g/kg seed or tebuconazole-Razil Easy at 1 ml/kg seed)(Bradford 1986, Bista 2018).

3. Time of Sowing

The optimal time to sow rice during the kharif season is crucial to the success of DSR. This period should be completed 10–15 days prior to the start of the monsoon in order to facilitate early root establishment, prevent emergent weeds, and sow the following crop on schedule. The ideal period to plant DSR is ten to fifteen days prior to the start of the monsoon. In Uttar Pradesh, Haryana, and Punjab, the monsoon arrives around June 20–25, therefore the ideal time to plant is between June 15 and June 25.

4. Selection of Varieties
Cultivar selection based on soil type and irrigation availability is crucial to achieving the targeted yield. Light textured sandy-loam soils are best suited for early to medium maturing varieties (100–135 days), whereas heavy textured clay is better suited for late maturing varieties (135–165 days). High yielding cultivars should generally be chosen taking into account the local environment or region. It has been shown that hybrid cultivars and basmati types are better suited for DSR than others. Coarse and hybrid types, such as Arize 6129, PR-113, 114, 124, PRH-10, RH 664, Pusa 44, RH 2014, HKRH 1, 401, Sahyadri, etc., were ideal for DSR. Basmati types, such as Pusa 1121, CSR-30, Pusa Basmati -1, Pusa 2511, Basmati super, and Basmati 385

5. Sowing Method and Depth
A multi-crop planter equipped with inclined plates seed metering devices and inverted T-type tynes should be used to drill rice precisely. For both fine and coarse basmati rice, the ideal seed rate with a zero-till drill is 15-20 kg/ha and 20–25 kg/ha, respectively; for hybrids, it is 8–10 kg/ha. The depth of seeding has a direct effect on germination and should not be greater than 3 cm in order to get the desired crop stand. This is because planting seeds below 3 cm would negatively impact seed emergence since they will dry out the upper soil layer (Kakraliya et al 2016, Singh et al 2020).


Figure 6: Seedling emergence after Dry Direct Sowing of Rice followed by irrigation

6. Water Management
When a young leaf begins to roll in the morning or evening, or when hairy fissures begin to appear in the top layer of soil, provide irrigation. Accurate water management during crop emergence (the first 7–15 days following seeding) is crucial for DSR (Balasubramanian and Hill 2002; Kumar et al., 2009). To prevent seed rotting, care must be taken to prevent the field from being too wet.

To guarantee adequate rooting and seedling establishment, as well as inhibiting germination of weed seeds, the field can be saturated when the crop is at three-leaf stage (Sandhu et al 2021, Bista 2018, Balasubramanian & Hill 2002).

7. Nutrient Management
In DSR, land is often prepared in dry soil; it has distinct nutrient dynamics than TPR and stays aerobic during the crop season. The availability of micronutrients like Fe and Zn as well as other nutrients including N, P, and S is decreased in DSR. Furthermore, compared to TPR, N losses from denitrification, volatilization, and leaching are probably significant in dry-DSR. Blanket applications of N at 120–150 kg ha-1, P2O5 at 60 kg ha-1 and K2O at 40 kg ha-1 in addition to ZnSO4 at 25 kg ha-1, is recommended . As a basal dose, one-fourth of N and the entirety of P2O5 and K2O are applied to light soil. At maximal tillering and panicle initiation stages, the remaining N should be top dressed in two splits. While the general recommendations for NPK fertilisers are the same for both DSR and TPR, DSR recommends a somewhat greater amount of N (22.5–30 kg ha–1). This is done to make up for the higher losses and decreased N availability during the early crop stages (Bista 2018, Singh et al 2020).

8. Weed Management
Nearly 350 different species of weeds are known as weeds of rice, out of which majority are grasses, followed by sedges and broadleaf weeds. For management of weeds, preventive, cultural, mechanical and chemical methods are under practice. Preventive methods include using weed free seeds, prevention of weed seed dispersal and crop rotation. Cultural methods include stale seed bed method, increasing competition in field by adopting high seed density. Manual and mechanical weeding are done under physical methods but these are labour intensive and require more monetary inputs. The most suitable method of weed management in DSR is chemical method where herbicides (pre-emergence and selective) are used to supress weeds. Pendimethalin(1000g a.i/ha) and Pyrazosulfuron(20g a.i/ha) are used as pre-emergence herbicides at 0-3 Days After Sowing while Bispyribac sodium at 25-30g a.i/ha is used as early post emergence herbicide at 10-14 DAS (Saravanane et al 2021)

VII. FUTURE PROSPECT

To encourage adoption, additional efforts are to be made to promote direct seeding among rice farmers in appropriate locations as a feasible substitute for transplanting. Increasing drainage and irrigation on farms could be crucial for this. DSR can outperform TPR in yields by optimising management techniques. In order to reduce the yield gap between DSR and TPR, which is farmers' main concern, training on effective weed control strategies, including good land preparation and water management as preventive measures, is essential (Bhullar et al 2018).

New and improved rice types that are suitable for DSR are needed on the research front. Comprehensive spectrum weed control still requires more research on weed management, particularly weedy rice control, despite the use of numerous integrated techniques. Since the availability of micronutrients, primarily Fe and Zn, lowers DSR, further research is required to understand the nutrient dynamics in soils under DSR. Research on soil ecology in rice soils is also necessary. Different rice production systems require the development of a site-specific bundle of production technologies based on climatic and edaphic conditions as well as local resource availability. It is necessary to formulate anticipatory research and development strategies for an environment where DSR will be implemented (Chaudhary et al 2023).

VIII. CONCLUSION

DSR, with appropriate conservation techniques, has the ability to deliver comparable or better yields than TPR and appears to be a feasible solution to overcoming the problem of labour and water scarcity. Despite controversy, well managed DSR can offer equivalent yields as TPR. Weeds, if not managed properly, can cause DSR crops to fail partially or completely. The energy, water, and labour-intensive aspects of typical puddled transplanted rice have contributed to the issue of environmental degradation and groundwater depletion. As an alternative, direct seeded rice should be used because it is economically, technically possible, and environmentally safe.

REFERENCES

1. Tyagi, R., & Chander, J. K. S. (2020). Comparative analysis between direct seeded rice and conventional transplanted rice method. The Pharma Innovation Journal, 9(6), 236-238.
2. Jat, R. K., Meena, V. S., Kumar, M., Jakkula, V. S., Reddy, I. R., & Pandey, A. C. (2022). Direct seeded rice: strategies to improve crop resilience and food security under adverse climatic conditions. Land, 11(3), 382.
3. Chaudhary, A., Venkatramanan, V., Kumar Mishra, A., & Sharma, S. (2023). Agronomic and environmental determinants of direct seeded rice in South Asia. Circular Economy and Sustainability, 3(1), 253-290.
4. Ladha, J. K., Kumar, V., Alam, M. M., Sharma, S., Gathala, M., Chandna, P., ... & Balasubramanian, V. (2009). Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice-wheat system in South Asia. Integrated crop and resource management in the rice–wheat system of South Asia, 69-108.
5. Singh, H., Kumar, P., & Kaur, A. (2020). Direct Seeded Rice: What, Why and How?. INDiAN FARmER, 656.
6. Bautista, A. P. G., Mataia, A. B., Austria, C. P., Tiongco, M. M., & Laborte, A. G. (2023). Adoption and Performance of Direct-seeded Rice (DSR) Technology in the Philippines. Philippine Journal of Science, 152(1).
7. Xu, S., Fei, Y., Wang, Y., Zhao, W., Hou, L., Cao, Y., ... & Wu, H. (2023). Identification of a Seed Vigor–Related QTL cluster associated with weed competitive ability in direct–seeded rice (Oryza Sativa L.). Rice, 16(1), 45.
8. Raj, S. K., & Syriac, E. K. (2017). Weed management in direct seeded rice: A review. Agricultural Reviews, 38(1), 41-50.
9. Pathak, H., Tewari, A. N., Sankhyan, S., Dubey, D. S., Mina, U., Singh, V. K., & Jain, N. (2011). Direct-seeded rice: potential, performance and problems-Areview. Current Advances in Agricultural Sciences (An International Journal), 3(2), 77-88.
10. Kalita, J., Ahmed, P., & Baruah, N. (2020). Puddling and its effect on soil physical properties and growth of rice and post rice crops: A review. Journal of Pharmacognosy and Phytochemistry, 9(4), 503-510.
11. Song, K., Zhang, G., Yu, H., Huang, Q., Zhu, X., Wang, T., ... & Ma, J. (2021). Evaluation of methane and nitrous oxide emissions in a three-year case study on single rice and ratoon rice paddy fields. Journal of Cleaner Production, 297, 126650.
12. Ramesh, T., & Rathika, S. (2020). Evaluation of rice cultivation systems for greenhouse gases emission and productivity. Int. J. Ecol. Environ. Sci, 2, 49-54.
13. Singh, K. (2011). Groundwater depletion in Punjab: measurement and countering strategies. Indian Journal of Agricultural Economics, 66(4).
14. Grigg, D. B. (1974). The agricultural systems of the world: an evolutionary approach (Vol. 343). Cambridge University Press.
15. Marasini, S., Joshi, T. N., & Amgain, L. P. (2016). Direct seeded rice cultivation method: a new technology for climate change and food security.
16. Chaudhari, S. K., Bardhan, G., Kumar, P., Singh, R., Mishra, A. K., Rai, P., ... & Sharma, D. K. (2015). Short-term tillage and residue management impact on physical properties of a reclaimed sodic soil. Journal of the Indian Society of Soil Science, 63(1), 30-38.
17. Gill, G., Humphreys, E., Kukal, S. S., & Walia, U. S. (2011). Effect of water management on dry seeded and puddled transplanted rice. Part 1: Crop performance. Field Crops Research, 120(1), 112-122.
18. Dawe, D. (2005). Increasing water productivity in rice-based systems in Asia–past trends, current problems, and future prospects. Plant Production Science, 8(3), 221-230.
19. Balasubramanian, V., & Hill, J. E. (2002). Direct seeding of rice in Asia: emerging issues and strategic research needs for the 21st century. Direct seeding: Research strategies and opportunities, 15-39.
20. Kumar, A., Kumar, S., Dahiya, K., Kumar, S., & Kumar, M. (2015). Productivity and economics of direct seeded rice (Oryza sativa L.). Journal of Applied and Natural Science, 7(1), 410-416.
21. Joshi, E., Kumar, D., Lal, B., Nepalia, V., Gautam, P., & Vyas, A. K. (2013). Management of direct seeded rice for

enhanced resource-use efficiency. Plant Knowledge Journal, 2(3), 119-134.

22. Ito, A., Inoue, S., & Inatomi, M. (2022). Model-based evaluation of methane emissions from paddy fields in East Asia. Journal of Agricultural Meteorology, 78(2), 56-65.
23. Prihar, S. S., Khepar, S. D., Singh, R., Grewal, S. S., & Sondhi, S. K. (1990). Water resources of Punjab-a critical concern for the future of its agriculture.
24. Sun, H., Zhou, S., Fu, Z., Chen, G., Zou, G., & Song, X. (2016). A two-year field measurement of methane and nitrous oxide fluxes from rice paddies under contrasting climate conditions. Scientific Reports, 6(1), 28255.
25. Gill, M. S., Kumar, A., & Kumar, P. (2006). Growth and yield of rice (Oryza sativa) cultivars under various methods and times of sowing. Indian Journal of Agronomy, 51(2), 123-127.
26. Kakraliya, S. K., Singh, L. K., Yadav, A. K., Jat, H. S., Kakraliya, S. S., Choudhary, K. M., & Datta, A. (2016). Smart package and practices for direct seeded rice (DSR). Innovative Farming, 1(2), 49-55.
27. Bradford, K. J. (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress. HortScience, 21(5), 1105-1112.
28. Bista, B. (2018). Direct seeded rice: A new technology for enhanced resource-use efficiency. International Journal of Applied Sciences and Biotechnology, 6(3), 181-198.
29. Sandhu, N., Yadav, S., Kumar Singh, V., & Kumar, A. (2021). Effective crop management and modern breeding strategies to ensure higher crop productivity under direct seeded rice cultivation system: A review. Agronomy, 11(7), 1264.
30. Balasubramanian, V., & Hill, J. E. (2002). Direct seeding of rice in Asia: emerging issues and strategic research needs for the 21st century. Direct seeding: Research strategies and opportunities, 15-39.
31. Bhullar, M. S., Singh, S., Kumar, S., & Gill, G. (2018). Agronomic and economic impacts of direct seeded rice in Punjab. Agricultural Research Journal, 55(2).
32. Pathak, H., Bhatia, A., Jain, N., & Aggarwal, P. K. (2010). Greenhouse gas emission and mitigation in Indian agriculture–A review. ING bulletins on regional assessment of reactive nitrogen, bulletin, 19, 1-34.
33. Saravanane, P., Pavithra, M., & Vijayakumar, S. (2021). Weed management in direct seeded rice. Indian Farming, 71(04), 61-64.