

# Transforming rice cultivation through organic direct-seeded rice

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*Organic direct-seeded rice (DSR) is an emerging practice that integrates the principles of organic farming with the advantages of direct seeding, offering a sustainable alternative to traditional transplanting methods. Organic DSR eliminates the need for puddling and nursery transplantation, thereby reducing labour, water usage, and greenhouse gas emissions. In organic DSR, chemical inputs are replaced with organic amendments like compost, green-manure, and biofertilizers, enhancing soil health and biodiversity. The practice improves soil structure and microbial activity, leading to better nutrient cycling and carbon sequestration. Organic DSR is particularly relevant in water-scarce regions, as it significantly reduces irrigation needs compared to conventional transplanting systems. However, challenges, such as weed management, nutrient supply, and ensuring adequate plant establishment without synthetic inputs, need to be addressed for its broader adoption. Future research should focus on optimizing organic inputs and developing integrated weed management strategies to enhance productivity and ensure sustainability. Organic DSR holds the potential to contribute significantly to climate-resilient agriculture by reducing water usage, improving soil fertility, and enhancing ecosystem services while promoting healthier and more sustainable rice production systems.*

**Keywords:** Direct-seeded rice, Greenhouse gas emissions, Nutrient management, Organic farming, Productivity, Weed management

Rice (*Oryza sativa* L.) is a staple food for nearly 800 million Indians, playing a pivotal role in the nation's diet, economy, and employment. With the demand for organic products rising steadily, the organic produce market is projected to reach between USD 1.6 billion and 2 billion by 2024, growing at an impressive compound annual growth rate of 12% to over 21%. By 2032, this market could expand to USD 10 billion, driven by increased demand for organic cereals, fruits, vegetables, dairy, and processed foods. Specifically, India's demand for organic rice is expected to hit 45 million tonnes by 2025, according to International Federation of Organic Agriculture Movements (IFOAM). Global organic rice production

is steadily increasing, with an estimated 0.7–1 million ha under cultivation and annual production of 2.5–3 million metric tons. Asia, led by India, Thailand, the Philippines, and China, dominates organic rice farming, while demand continues to grow in Europe and North America (FiBL and IFOAM 2023). India is the largest exporter of organic basmati rice, while Thailand is a leading producer of organic jasmine rice. USA and Italy focus on producing organic specialty rice varieties. Meeting this growing demand requires sustainable rice production methods that optimize water use and labour efficiency. Traditional rice farming faces challenges, such as water scarcity, heavy chemical use, high labour costs, and

escalating production expenses. The surge in organic rice demand has widened the gap between supply and demand, presenting a major opportunity. To fully leverage the global organic rice market, India must urgently increase the area under organic cultivation and boost productivity. Scientists, researchers, and farmers must develop strategies to maximize production sustainably while conserving resources in rice-based cropping systems. Organic rice farming is not a new concept—it has been practiced for generations, particularly in states like Sikkim, Arunachal Pradesh, Manipur, and Uttarakhand, where resource-constrained farmers have traditionally avoided chemical fertilizers. However, these organic

rice systems tend to be far less productive than the input-heavy conventional farming methods. A major barrier to the wider adoption of organic rice farming is the significant yield gap between conventional and organic systems. Direct-seeded rice (DSR) under organic practices could offer a promising solution to bridge this gap. This approach may also reduce the emission of greenhouse gases like methane (CH<sub>4</sub>). Organic DSR production involves crop residue recycling, crop rotation, legume integration, green-manuring, off-farm waste recycling, and biological pest control without agrochemicals. However, the potential issues in weed management, soil fertility, and pests and diseases are key issues with this method. Identification of critical yield-limiting factors and understanding the system ecology and production dynamics are important aspects that should be promoted towards efficient organic DSR. Based on such knowledge, effective strategies can be designed to enhance organic DSR cultivation.

#### What are the needs for organic DSR?

Traditional rice cultivation methods are resource-intensive, demanding large quantities of water and labour. Additionally, the heavy use of synthetic fertilizers, pesticides, and herbicides in paddy farming has led to soil degradation, water pollution, and negative impacts on human health and biodiversity. Organic DSR offers a

solution to these challenges through the following key features:

**Water conservation:** Traditional rice farming is highly water-intensive, with 3,000–5,000 L of water needed to produce 1 kg of rice. In Asia, rice irrigation consumes around 50% of all irrigation water and contributes to global freshwater depletion, causing significant drops in water tables. Organic DSR offers a water-efficient solution by avoiding continuous flooding. Compared to transplanting, DSR requires far less water, especially when combined with methods like alternate wetting and drying (AWD), making it an essential practice for water-scarce regions while maintaining rice production.

**Labour scarcity:** Labour scarcity is an increasing challenge in rice cultivation due to urbanization, migration, and an aging farming population. Organic DSR helps mitigate this issue by requiring significantly less labour than traditional transplanting methods. It eliminates the need for nursery preparation, seedling care, and transplanting, making rice cultivation more feasible in labour-scarce areas and more cost-effective for smallholder farmers by reducing production costs. The DSR practice has the potential to reduce labour requirements by approximately 28–30% compared to transplanted rice (Bhushan 2007). Approximately 10 labourers can be saved in rice nursery preparation, and 25 labourers can be reduced

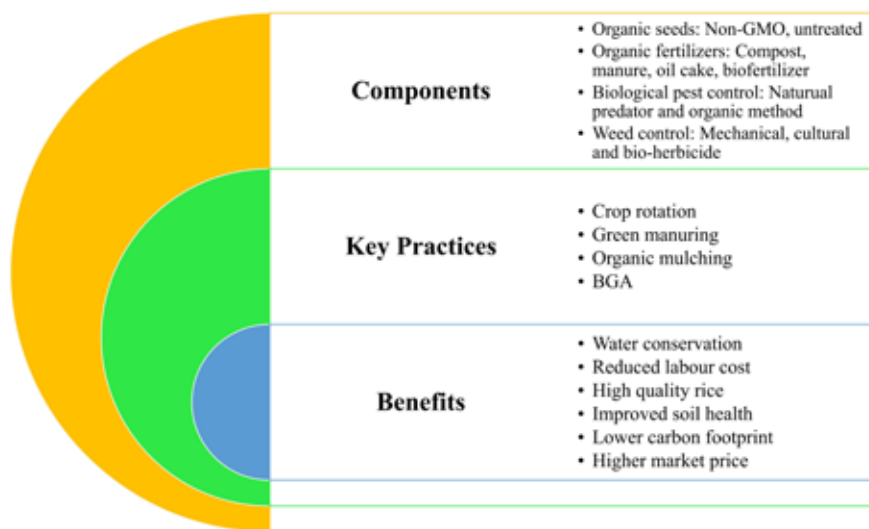
during transplanting, compared to conventional transplanted rice. Hence, it can lower the cultivation cost by approximately ₹10,000/ha.

**Environmental sustainability:** Conventional rice farming depends heavily on synthetic fertilizers, pesticides, and herbicides, which harm soil health, pollute water, and reduce biodiversity. In contrast, organic DSR uses natural inputs, preserving ecological balance and avoiding harmful chemicals. This approach improves soil health, reduces pollution, supports biodiversity, and helps mitigate climate change by lowering methane emissions through reduced flooding. DSR reduces water consumption by 25–30% by eliminating the need for continuous flooding. The alternate wetting and drying (AWD) irrigation technique further improves water-use efficiency. Additionally, by minimizing anaerobic conditions in flooded fields, DSR helps lower methane emissions by 30–40%.

**Economic viability and farmers' livelihoods:** Rising labour costs have made transplanting uneconomical. Organic DSR eliminates this step, lowering labour and fuel costs, and making it a more affordable option. Additionally, organic rice commands higher market prices, increasing farmers' income. Kaur and Singh (2017) reported that in Punjab, direct seeding practices yielded the highest net income, ranging from ₹18,587–₹19,039/ha, with a benefit-cost (B:C) ratio of 2.29–2.33, outperforming conventional transplanting methods.

#### How to practice organic DSR?

For organic DSR, seeds can be treated with *Azospirillum* and phosphorus-solubilizing bacteria (PSB) at a rate of 10 g/kg of seeds. To enhance plant nutrition, organic manures, crop residues, or green manures should be applied based on soil test recommendations for the specific area. It is important to consider the quantity of organic sources, nutrient concentrations, moisture content, and their contribution to plant uptake and crop requirements. During land preparation, 10 t/ha of farmyard



Basic principle of organic DSR cultivation

manure (FYM) should be applied, along with 5 t/ha of paddy straw and 10 t/ha of in-situ grown Dhaincha or sunhemp. These organic materials will supply approximately 150 kg of nitrogen (N), 40–50 kg of phosphorus, and 100–120 kg of potassium to the crop, fulfilling its major nutrient needs based on their mineralization and release. Additionally, bio-fertilizers like *Azospirillum* or PSB should be mixed with 25 kg of FYM or vermicompost and applied at a rate of 2–3 kg/ha just before sowing. Some of the key management practices are described below:

**Variety selection and seed treatment:** Choosing the right variety is critical for optimal yields in organic DSR, as it depends on soil type and irrigation availability; for irrigated sandy loam soils, early to medium-duration varieties (100–135 days) are recommended, while medium to late-duration varieties (135–165 days) suit heavy clay soils, with suitable basmati options including PR 115, *Pusa Basmati* 1121, *Punjab Mehak* 1, CSR 30, *Pusa Basmati* 1, and *Taraori Basmati*, all of which should adapt well to local conditions, resist common pests and diseases, and be compatible with direct seeding. Optimal seeding rates for zero-till ferti-drill sowing are 15–20 kg/ha for fine grains and basmati, 20–25 kg/ha for coarse grains, 8–10 kg/ha for hybrids, and 25–30 kg/ha for broadcasting. The success of organic DSR hinges on proper variety selection and effective seed treatment, with options to treat seeds using organic fungicides or bio-agents to prevent seed-borne diseases, while soaking them in neem extracts can improve germination and promote healthy crop growth.

**Weed management:** Weed management is the most significant challenge in direct-seeded rice (DSR). Organic DSR employs a range of effective weed control measures, starting with cultural practices such as early sowing, proper spacing, the stale seedbed technique, surface mulching with organic materials like straw or grass, and incorporating cover crops

such as *Sesbania rostrata*, *Phaseolus radiatus*, and *Vigna unguiculata*, along with green manuring. Mechanical weeding methods, including the use of rotary weeders and hand weeding during critical growth stages, further support weed management. Biological control is achieved through azolla cultivation, which suppresses aquatic weeds—applying 1 t/ha can achieve 72% efficiency against *Cyperus difformis* and *Marsilea minuta* and using bio-herbicides like Collego, Devine, and Biomal. Additionally, botanical herbicides such as neem extracts and natural citrus oil are used to inhibit weed growth effectively. The application rates for Collego, Devine, and Biomal are 4.5–9.0 g active spores/ha, 1.0–2.5 kg/ha, and 4.5–10 g spores/ha, respectively. These bio-herbicides are typically applied as an early post-emergence treatment, targeting weeds at the 2–4 leaf stage. A well-known bioherbicide that effectively controls weeds without affecting yield is the phytotoxic water extract from *Sorghum bicolor*. The application of sorghum water extract (15 L/ha) reduced the biomass of *Echinochloa crusgalli* by 40%, leading to an 18% increase in rice production (Islam *et al.* 2024).

**Water management:** Direct-seeded rice (DSR) uses less water than transplanting, but still requires management. Irrigation management in DSR is crucial for water conservation and crop productivity, reducing water consumption by 25–30% compared to transplanted rice. Alternate wetting and drying (AWD) are a popular method for organic DSR, allowing fields to dry between irrigations. This practice saves water and reduces methane emissions. Mulching protects topsoil, improves aeration, conserves moisture, increases water retention, encourages soil fauna, enhances nutrient status, and controls weeds. During sowing to germination (0–7 DAS), light irrigation is necessary to maintain soil moisture for proper germination and uniform plant establishment. In the vegetative stage (7–25 DAS), irrigation should

be provided every 5–7 days to prevent moisture stress. From tillering to flowering (25–65 DAS), AWD method is recommended, with irrigation applied when the soil dries 5 cm below the surface or when hairline cracks appear in the field. During grain filling to maturity (65–100 DAS), irrigation should be gradually reduced and stopped around 20 days before harvest to facilitate drying. The total water requirement for DSR is 900–1200 mm per crop cycle, which is significantly lower than transplanted rice. Water application is most efficient using AWD and furrow irrigation to optimize water use and improve crop productivity.

**Nutrient management:** Organic DSR depends on various natural nutrient sources, including compost, vermicompost, farmyard manure, fresh cow urine, poultry and pig manure, and green manures, such as sun-hemp, dhaincha, and cluster bean, with sheep and goat droppings offering higher nutrient content than farmyard manure and compost. Soil testing plays a crucial role in guiding the application of organic fertilizers, enhancing nutrient use efficiency, and green manuring typically increases yields by 30–50%. Additional organic nutrient sources include vermiwash at a 5–10% dilution, a foliar spray combining 0.5 L of vermiwash and 0.5 L of cow urine in 10 L of water, as well as *Panchagavya*, *Dasagavya*, *Ghanjeevamrit*, *Jeevamrutham*, and *Beejamrutam*. Application of potassium silicate along with FYM was also found to be a better nutrient management for organic DSR.

**Insect-pest and disease management:** In organic rice farming, pest and disease management relies on biological control, cultural practices, and natural inputs instead of synthetic chemicals. To control insect pests like stem borers, leaf folders, brown planthoppers (BPH), and rice hispa, farmers use botanical extracts, biopesticides, and natural predators. Neem oil (5% solution, 5 ml/L water) should be sprayed at 10–15 day intervals from the vegetative to flowering stage to prevent insect pests. *Beauveria*



(a) Potassium silicate spraying on organic direct-seeded rice



(b) Organic direct-seeded rice at the maturity stage

*bassiana* (2.5 kg/ha) and *Metarhizium anisopliae* (2.5 kg/ha) should be applied at the early pest infestation stage. *Trichogramma* sp. parasitoids (50,000 eggs/ha) should be released at the egg-laying stage of borers. For disease management, *Trichoderma* sp. (5 g/kg seed) should be used for seed treatment before sowing, and 2.5 kg/ha in compost should be applied at the tillering stage. Regular monitoring, crop rotation, and balanced fertilization further enhance organic pest control.

#### What are the major constraints for organic DSR?

Despite its various potential benefits, organic direct-seeded rice faces several limitations, including high susceptibility to weed infestations, particularly from hard-to-manage species, multiple

flushes of weeds at different growth stages, a lack of chemical-free weed control measures, and challenges in providing adequate nutrient supply, all of which can significantly impact the performance and yield of organic DSR. Farmers require guidance on crop rotation techniques and methods to prevent herbicide resistance, as organic DSR may necessitate a different approach to weed management compared to conventional DSR.

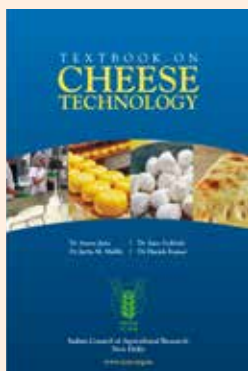
#### SUMMARY

With the anticipated rise in demand for organic and sustainable food, organic direct-seeded rice (DSR) emerges as an optimal solution for achieving sustainability and minimizing environmental impacts while maintaining productivity. This approach merges the efficiency

of direct seeding with organic farming principles, offering a pathway for more sustainable rice production that meets the needs of both farmers and consumers. However, successful implementation hinges on comprehensive planning and continuous education for farmers, supported by agricultural extension services that provide access to suitable varieties and tools. By effectively addressing the challenges associated with organic farming and capitalizing on the benefits of DSR, we can foster self-reliance among farmers, safeguard the environment, and encourage a harmonious relationship among plants, animals, and humans, ultimately contributing to sustainable development.

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