

Review Article

Direct-Seeded Rice in Nepal

Razan Malla^{1*}¹Soil Scientist, Soil Science Division, Khumaltar Lalitpur, Nepal

Article History

Received: 18.01.2021

Accepted: 21.03.2021

Published: 26.03.2021

Journal homepage:

<http://www.easpublisher.com>

Quick Response Code



Abstract: To over half the world's population, rice is the primary staple food. In recent years, there has been a shift from transplanted rice to direct-seeded rice cultivation mainly driven by seasonal scarcity of agricultural labor, increasing water scarcity, and high cost of production. Labor constraints mean sowing and transplanting are often delayed, resulting in yield losses. It is cost and time intensive for farmers. It causes adverse effects to soil and environment. Because of the low input demand, direct-seeded rice (DSR) has gained a lot of attention. Direct seeded rice refers to the process of developing seed crops from field seeds instead of transplanting seedlings. Three methods of direct seeding are known, namely: dry-DSR, wet-DSR and water seeding. Precise land grading, good crop establishment, accurate water management, weed management, and nutrient management are the most important prerequisites for successful direct-seed rice crop. There are no varieties to date specifically targeted for DSR but many of the inbred varieties and hybrids bred for puddled transplanted are found to be suitable. Direct seeding follows the aerobic cultivation of paddy, so the nutrient dynamics are altered. Several key nutrients like N, P, S, Zn, and Fe are likely to be a constraint. The infestation of weeds can cause significant loss of DSR yield.

Keywords: direct-seeded Rice, nutrient, water, weed management, resource conservation.

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INTRODUCTION

Rice (*Oryza sativa L.*) is the staple food for almost 3 billion people that is about 50% of the world's population. At least 114 countries grow rice. It is projected that by 2025, the world's farmers will need to grow around 60 per cent more rice than they are currently producing to meet the food demands of the world's expected population at the time [1]. Throughout Asia ninety percent of all rice is cultivated and eaten.

In Nepal, rice contributes about 21% to the agriculture gross domestic product. The national average yield of rice (3.76 t ha⁻¹) is far below the Asian average [2]. More than 70% of the rice growing areas in Nepal fall in terai region followed by hills and mountains. It is estimated that more than 90 percent of rice is grown in puddled soil in Nepal [3]. Traditional

transplanted puddled rice is valuable for resource use efficiency. It conserves water, increases nutrient availability while suppressing the weeds [4]. Puddling over time degrades the soil; soil aggregates are dissolved; permeability is reduced and hard pans of soil formed at shallow depths [5]. The need for ponded water also delays the transplantation of rice for 1 to 3 weeks [6].

There has been a change in recent years from transplanted rice to direct-seeded rice cultivation in many Southeast Asian countries [7]. This shift was mainly driven by the increasing water scarcity, shortage of labor and high cost of production. Much effort and new ideas are emerging to improve rice production and productivity [8]. One of such emerging concepts is, Direct Seeded Rice.

Table-1: Grain yield comparisons between conventional puddled transplanting and various alternative tillage and crop establishment methods in Nepal

SN	Tillage and CE methods	No. of studies	Adjusted mean yield (t ha ⁻¹)	p-value
1	CT-TPR	14	4.80	-
2	CT- wet seeding (CT-wet-BCR, CT-wet-DSR)	6	5.00	NS
3	CT/RT-dry-DSR	15	4.80	NS
4	Bed-dry DSR	3	4.55	NS

Source: Kumar and Ladha, 2011.

METHODOLOGY

Systematic reviews of different published and unpublished papers, journal and books were done and their conclusions were drawn and summarized the evidence by use of explicit methodology. The results of the different articles were summarized in this paper.

RESULTS AND DISCUSSIONS

Direct seeded rice

Direct seeded rice refers to the process of developing seed crops from field seeds instead of transplanting seedlings [9]. Direct seeding eliminates three main basic operations, namely puddling, transplantation and the management of standing water. In addition to higher economic returns, DSR crops are quicker and easier to grow, have shorter durations, less labor intensive, less water usage [10], fewer methane emissions and conducive to mechanization [11]. Some reports indicate DSR yields close to or even higher yields with good management practices. DSR yields are often lower than rice transplanted, mainly because of poor crop population, high panicle sterility and higher

weed infestations [12]. High infestation of weeds and nutrient deficiencies are essential constraints for wider adoption of DSR.

Direct seeding was the most common prior to the 1950s but was slowly replaced by puddled transplantation [13]. Three methods of direct seeding are known, namely: dry-DSR, wet-DSR and water seeding. Wet-DSR is common where there is a shortage of labor. It is practiced in Malaysia, Vietnam, Thailand, and Srilanka [7]. Water seeding is done in lands with a history of weed problems. Dry-DSR is the most popular method among all amidst the looming water and labor shortages and changing climatic scenario. It is popular in the upland rainfed ecosystem. Dry seeding in rainfed lowland, upland, and flood-prone areas in Asia is extensively practiced, while wet seeding in irrigated areas remains common practice [14, 15]. Direct seeding in Nepal is done in dry fields on uplands. This practice is more prevalent in the hills in uplands. Direct seeding is also done in western Nepal in lowlands where labor is short and the eastern lowlands where water gets stagnated during monsoon.

Table-2: Classification of direct-seeded rice (DSR) system.

System of direct seeding	Seed bed condition and environment	Sowing method	Suitable ecology
Direct seeding in dry bed	Dry seeds are sown in dry and mostly aerobic soil	Broadcasting, Drilling or sowing in rows at depth of 2-3 cm	Mainly in rain fed area, some in irrigated areas with precise water control
Direct seeding in wet bed	Pre germinated seeds sown in puddled soil, may be aerobic or anaerobic	Various	Mostly in favorable rainfed lowlands and irrigated areas with good drainage facility
Direct seeding in Standing Water	Dry or Pre germinated seeds sown mostly in anaerobic condition in standing water	Broadcasting on standing water of 5-10 cm	In areas with red rice or weedy rice problem and in irrigated lowland areas with good land leveling

Source: Joshi *et al.*, [41].

Land preparation

DSR can be achieved whether through conventional tillage or through conservation tillage. The decision as to whether or not the soil should be cultivated depends on leveling requirements, the availability of appropriate equipment, weeding and crop rotation. For conventional till the field should be cultivated to a depth of 5-10cm and pulverized to maintain good soil tilth. Any existing weeds are killed with a non-selective herbicide. Care should be given to only use herbicides when the weeds are in active production stage.

Proper land leveling is an important prerequisite for DSR. Laser leveling is a good option but may not be feasible for all. Use of locally available equipment's like raiser and planking can be equally effective proper leveling of land is a significant precondition for DSR. Laser leveling is a decent choice, but it is difficult for anyone to accomplish. The use of local equipment can be equally efficient, such as raiser and planks. If farmers do not have access to levelling equipment's, measuring water depth at various locations when the field is flooded can give a fair idea

of field's levelness. An even irrigation field allows for a uniform crop base and improves the weed control and efficiency of fertilizer use [16]. Land leveling saves 20-25 percent of irrigation water [17]. DSR performance is associated to land leveling accuracy. Existing weeds should be burned with herbicidal products such as paraquat (@ 0.5 kg a.i. ha-1 and glyphosates @ 1.0 kg a.i. ha-1) for zero tilled direct seeded rice [18]. Summer ploughings are desirable in areas with heavy weed infestations.

Time of sowing

If irrigation is available, sowing of the crop is best 10–15 days before the monsoon starts [19, 20]. Optimal planting time means that the total yield is increased by up to 30% [21]. The ideal period for dry rice in the mid-hills is in the middle of May while the best period in the foothills is from late May to early June. The best time in the Terai is between the end of May and the beginning of June. The risk of heavy rain shortly after planting is higher, which will affect the establishment, particularly for clayey soil. The monsoon rain normally starts later in the western and central part of Terai and can be seeded during the first week of

June. However, the earlier the crop is sown, the greater the need for irrigation. Direct seeding in the lowlands of eastern Nepal is done in standing water from the monsoon which continues to do so even after harvest till January and February. So seeding is done in April-May in residual soil moisture. The rice germinates and becomes 10-15 cm. tall at the break of monsoon. Photoperiod-sensitive varieties of rice are grown there.

In the far west, direct-seeding is done after one or two rainfalls, when this soil has sufficient moisture to germinate the seed. In this condition, rice and weeds germinate together. So, weeds are a problem. When rice plants are 20-25 cm. tall, they are plowed with a thin plow. By this action, the rice population becomes thin but weeds are controlled to some extent.

Table-3: Effect of sowing dates on grain yield and yield components at Parwanipur, Nepal

Sowing date	Tillers/m ²		Grains/panicle		1000-grain wt. (g.)		Grain yield (kg/ha)	
	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00
15 June	240	316	100	99	22.2	24.2	4357	4497
29 June	186	277	105	81	21.9	23.9	4357	4282
14 July	166	258	92	86	21.1	23.9	2972	4146
29 July	169	199	71	65	20.7	23.7	2154	2266

Source: Shah and Bhurer, [42].

It was also reported that the reason for decline grain yield might be due to delayed panicle formation and grain filling in the season where temperature and solar radiation are less [22]. The earlier sown crop benefited from better sunshine and appropriate temperature that resulted into a more vigorous and extensive root system leading to high yields in early seeding.

Selection of varieties

Varieties of faster growth, enhanced early strength for weed competitiveness [23] and an effective

root system are sufficient for DSR to tap the moisture of the soil during dry periods. Early-heading rice varieties with a higher drought tolerance are better suited for the purpose of dry-seeded rice. The resistance to lodgings is also a beneficial attribute to direct seeding [24]. The high yield varieties have a higher percentage of germination and are more suitable. Local varieties are tall and lodging susceptible, so they are not suitable for direct-seeding. Broadcasting seeds on soil results in more lodging even with high yielding varieties.

Table-4: Effect of varieties on grain yield and yield components regardless of sowing dates

Varieties	Tillers/m ²		Grains/panicle		1000 grain wt. (gm.)		Grain Yield (kg/ha)	
	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00
Chaite 2	172	259	106	91	20.6	24.0	3366	4197
Radha 4	197	245	86	80	24.8	27.8	3757	3769
Chaite 6	213	302	78	72	20.9	22.8	3154	3777
Radha 11	180	245	97	87	19.6	21.1	2953	3447

Source: Shah and Bhurer, 2005.

Table-5: Suitable cultivars for DSR in the Terai and mid-hills of Nepal

Variety	Duration (Days)	Yield (kg/ha)	Region / situation
Hardinath-1	110-115	5.0	Terai and Inner Terai
Tarahara-1	115	4.2	Eastern and central Terai
Radha-4	120-25	3.2	Foothills and Terai region
Sukha-1	125	2.5-3.6	Terai and inner Terai, river basin
Sukha-2	125	3.3-3.5	Terai and inner Terai, river basin
Sukha-3	125	3.2-4.2	Terai and inner Terai, river basin
Ram Dhan	138-148	4.9	Chitwan
Sabitri	140-145	4.0	Terai and inner Terai
Samba-Sub-1	145-150	4.0	Officially not released but popular, Terai, inner Terai, irrigated and rainfed lowland
Sona Masuli	150-155	4.5	Terai (Officially not released but cover a large area in Central Terai)
Khumal-4	144	6.3	Mid hills
Khumal-8	158	9.8	Mid hills
Khumal-10	145	4.5	Mid hills
Gorakhnath	120-125	6-7	Terai, inner Terai, irrigated and rainfed lowland
Arize 6444	135-140	7-8	Terai, inner Terai, irrigated and rainfed lowland
Bioseed -786	120-125	7-8	Terai, inner Terai, irrigated and rainfed lowland
RH-245	120-125	5-6	Terai, inner Terai, irrigated and rainfed lowland
Loknath-505	120-125	5-6	Terai, inner Terai, irrigated and rainfed lowland
Raja	120-125	5-6	Terai, inner Terai, irrigated and rainfed lowland

Source: Guidelines for Dry Seeded Rice (DSR) in the Terai and Mid Hills of Nepal, 2014

Seed priming

Seed priming is an effective approach to address the drought stress as DSR is sown at a shallow depth (<2 cm) in advance of the monsoon rains [25]. Priming accelerates crop emergence and establishment. Usually, the rice seed is soaked for 24 hours and incubated for 48 hours before seeding. In the first place, the seeds are stored in a gunny sack overnight. The seed should be seeded shortly thereafter. Seeds can also be soaked in fungicide and antibiotics solution. Priming with imidacloprid increased the panicle numbers and filled grains per panicle [18]. Seed priming also decreased seeding requirements, but was counterproductive when the soil was near or at saturation [18].

Seed rates and seeding depth

High seed rates are used mostly in areas where the seed is broadcast to suppress weeds or when water seeded [26]. About 80-100 kg/ha seed rate is used. The seed rate is the same as for upland rice but double the rate of transplanted rice. In very dense populations, higher sterility and fewer grains per panicle are common [27]. Dense populations of plants with high seed levels may also establish conditions for disease, such as sheath blight [28, 29] and insects causing plants to lodge easily [30]. Seeding depth should not be kept more than 3cm for desired level of crop stand because of rapid drying of upper soil moisture.

Planting machinery

In order to ensure accurate and efficient seeding, the rice should be drilled with a multi-crop planter equipped with seed metering systems with inclined plate and inverted T-type tynes. Seed drills with inverted-T tynes are suitable for seeding into both tilled and non-tilled soil. It is possible to do better crop establishment with lower seed rate and more reliable plant-to-plant spacing with these precise seed metering planters [31]. Multi-crop planter can be used for seeding where there are few residues to work with. But in case of bulkier crop residues Turbo Happy Seeder should be used. In Nepal, 2-wheel tractor seed-cum fertilizer drills may be used for DSR on a small farm holding in the foothills, inner Terai and in the Terai

zone. The depth of seeding needs to be adjusted to achieve a seeding depth of 1-2 cm.

Nutrient Management

Direct seeding follows the aerobic cultivation of paddy, so the nutrient dynamics are altered [32]. Several key nutrients like N, P, S, Zn, and Fe are likely to be a constraint [33]. Besides, N losses in DSR are very high. Fertilizer recommendations for DSR are similar to that of transplanted rice except for a higher dose of N should be used to balance out the higher N losses [21]. A 100-120 kg N/ha in 3-4 splits and P₂O₅ at 40 kg/ha, K₂O at 30 kg/ha, and ZnSO₄ at 25 kg/ha (in Terai) is recommended. A full dose of P and K and 1/3 N as basal should be given at the moment of sowing. The remainder of the 2/3 dose of N would be better suited for tillering and panicle initiation [20]. IRRI uses a leaf color chart (LCC) to manage N [22]. Use of slow-release or controlled-release N fertilizers offers advantage due to their delayed-release thus reducing losses, labor cost and increasing efficiency [34]. But due to its heavy price, its use is limited. Zinc deficiency is a common problem in DSR [35]. Basal application of zinc to the soil has been found to be the safest way to prevent its deficiency. When Zn is not added during seeding, it can be added 30 days after sowing (DAS) and at panicle initiation as a foliar spray (0.5% zinc sulfate and 1.0% urea).

Water management

In Asia, the agricultural water share decreased from 98% in 1900 to 80% in 2000 and is expected to decrease further to 72% by 2020. Precise management of water is critical in direct-seeded rice, particularly during crop emergence phase (first 7-15 days) [36]. Water management should be such that the field can be irrigated and drained whenever needed. Initially, 3 cm, of water is needed. Water should not be excessive otherwise; tiller numbers will be reduced. Frequent irrigation is necessary to keep the soil moist in the root zone, particularly on lighter soils, which may require irrigation every few days. The topsoil should be kept near saturation during the active tillering process and the moving to the grain-filling point. The presence of hairline cracks on the soil surface is a general indicator for the need to irrigate clayey soils.

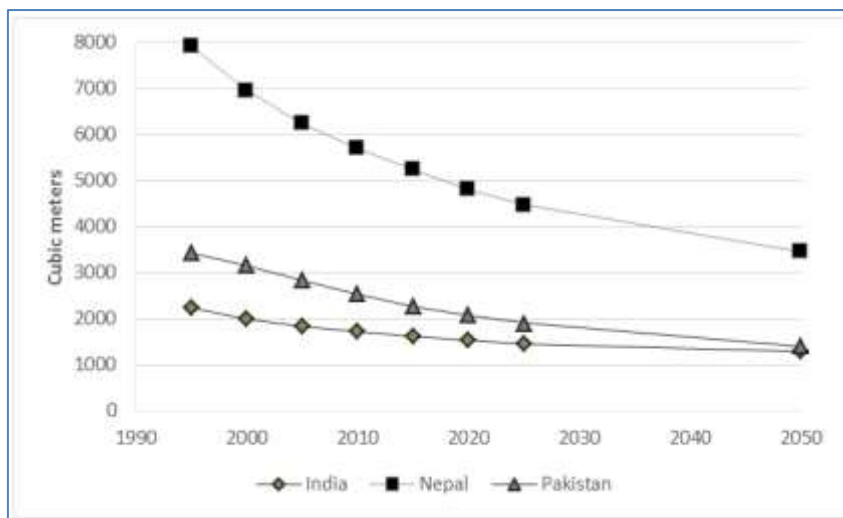


Fig-1: Per capita water availability in rice growing countries (1950-2050)

*2010-2050 projections based on population growth

Source: Modified from Gardner-Outlaw and Engelman [37]

Weed Management

Weed management is usually the major constraint for the successful production of DSR [19]. The DSR fields are infested with weeds of greater diversity [38]. Weed control is more costly and problematic because there is no water to reduce the development of weeds and rice and weeds continue to germinate together [39]. The germinating seeds remain on top of the soil, so there are more problems with birds, rats, snails, and weeds. In DSR areas, weedy rice has become a significant threat. It is highly competitive and causes major losses in rice yields [9]. FAO recommends a systematic approach integrating prevention, cultural and chemical methods suitable to effectively and sustainably manage weeds in Dry-DSR [40, 43].

Stale seedbed technique reduces weed emergence as well as the soil weed seed bank [13]. This technique is highly desirable in fields with long term weed problems. Weeds are encouraged to germinate with irrigation before being killed. When the soil can be

seeded, a non-selective herbicide can be used to kill the weeds and the crop should be planted without tillage. If the soil is dry, irrigation should be given before herbicide application. The retention of 15-20 cm of residues of the previous crop of wheat in zero tilled-DSR decreases DSR weeds and improves soil quality. Seeding rice and sesbania together and then killing sesbania with 2, 4-D approximately 25-30 DAS will reduce the weed population by almost half without any adverse effect on rice production [20].

A wide range of herbicides is available for controlling weeds. Preplant herbicides like Glyphosate (1.0 kg a.i. ha⁻¹ or 1% by volume) and paraquat (0.5 kg a.i. ha⁻¹ or 0.5% by volume) are recommended. Pendimethalin (1.0 kg a.i. ha⁻¹), oxadiargyl (0.09 kg a.i. ha⁻¹), and pyrazosulfuron (0.02 kg ha⁻¹) have also been reported to be effective as pre-emergence herbicides for DSR [18]. Postemergence application (15-25 days after sowing) of bispyribac sodium 25g a.i. ha⁻¹ was found very effective on most grasses. Bispyribac works well in saturated soil conditions [20, 21].

Table-6: Common weeds of DSR in Nepal

Grasses	Broad Leaf Weed	Sedges
<i>Echinochloa crusgalli</i>	<i>Eclipta sps.</i>	<i>Cyperus rotundus</i>
<i>Echinochloa colona</i>	<i>Caesulia axillaries</i>	<i>Cypeus difformis</i>
<i>Leptochloa alba</i>	<i>Ageratum sps.</i>	<i>Cyperus iria</i>
<i>Eragrostis tenella</i>	<i>Commelina sp.</i>	<i>Fimbristylis sps</i>
<i>Paspalum distichum</i>	<i>Amaranthus spinosus</i>	
<i>Digitaria ciliaris</i>	<i>Galinsoga ciliata</i>	
<i>Cyanodon dactylon</i>	<i>Alternanthera philoxeroides</i>	
<i>Panicumm dichotomiflorum</i>		
<i>Eleusine indica</i>		

CONCLUSION

Increased crop productivity must be achieved by increasing the efficiency of inputs at a lower cost

and by saving natural resources. DSR is one way to achieve it. DSR is being practiced with various tillage/land preparation and crop establishment modifications that are used to meet site-specific

requirements but have not gained popularity, although several research studies indicate its advantages over transplanted rice. DSR with effective management practices has the ability to achieve yields that are marginally lower or equal to that of TPR, which appears to be a feasible alternative to addressing labor and water shortages. Using this process, equivalent output can be obtained if weed and water control is done properly. A great deal needs to be done on nutrient dynamics in soils under DSR. Achieving appropriate land levelling is key to satisfactory crop establishment, water management and increasing productivity. A site-specific package of production technologies for different rice production systems needs to be developed in different rice production zones.

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Cite This Article: Razan Malla (2021). Direct-Seeded Rice in Nepal. *East African Scholars J Agri Life Sci*, 4(3), 75-81.