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Research Article

CROP MANAGEMENT STRATEGIES AND PRACTICES FOR IMPROVING WATER PRODUCTIVITY IN DRY-SEEDED RICE

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ABSTRACT
Conventional flooded rice cultivation in northwestern India is vital for India's food security (Timsina and Connor 2001). The small states of Punjab and Haryana, often referred to as the Food Bowl of the country produce 50% of the national rice production (Dhillon *et al*., 2010). Rice is normally irrigated almost continuously with water pumped from the groundwater (Sarkar *et al*., 2009). This overexploitation of groundwater threatens the sustainability of rice production. In the north-west Indo-Gangetic Plains have shown that rice can be successfully dry-seeded into nonpuddled soil, with or without prior cultivation. However, dry-seeded rice (DSR) needs to be sown in the main field 2–3 weeks earlier than the optimum transplanting time, at a time when evaporative demand is very high, thus increasing the need for irrigation prior to the time of transplanting. In addition, if the crop is grown without continuous flooding, as in upland rice, this may reduce water losses as evaporation, deep drainage, and surface runoff. However, many researchers have found similar input water productivity (WP_{I+R}) of DSR and conventional puddled transplanted rice (PTR) (Cabangon *et al*., 2002; Bhushan *et al*., 2007; Choudhury *et al*., 2007). The effects of DSR and PTR on water use and water productivity are not well understood, and depend on many factors, including climate, soil type, and crop management (Irrigation scheduling, Tillage, Mulching, Cultivars, Planting method etc.).

Keywords: *Dry-seeded Rice (DSR), Puddled Transplanted Rice (PTR), Water Productivity (WP)*

INTRODUCTION
Rice flourishes in an abundant water environment that best differentiates it from all other important crops. This unique environmental adaptation, however, could lead to this crop facing the fate of the dinosaurs in an era where water is increasingly becoming scarce and there is competition from other sectors. A reduction of 10% in water used in irrigated rice would free 150,000 million m^3, corresponding to about 25% of the total fresh water used globally for non-agricultural purposes (Klemm, 1999). Amount of water evapotranspired 917 (liters) to produce one kilogram of rice grain (Zwart and Bastiaanssen, 2004)**.** Productivity and profitability of rice is high under alluvial irrigated tract of Punjab. Higher water input (irrigation + rainfall) in rice is mostly due to its percolation losses. This has led to over-exploitation of ground water as indicated by alarming fall in water table. Average fall in water table in central region of the state has been more than 0.75m/year (Qadir *et al*., 2010; Humphreys *et al*., 2010).

Major Negative Effects of Ground Water Depletion

- Increasing energy requirement and cost of pumping groundwater
- Increasing tube well infrastructure cost
- Deteriorating ground water quality (Hira, 2009)

Increasing water scarcity has threatened the productivity and sustainability of the irrigated rice based systems in Asia. Water and labor scarcity demand a major shift from puddled transplanting (PTR) to direct seeding of rice (DSR). In direct seeded rice seeds are sown directly in the main field instead of transplanting rice seedlings.

Types of Direct Seeded Rice (DSR)

- Wet-DSR (primarily done for labor shortage) - Wet-DSR involves changing rice establishment methods only (from transplanting to direct seeding in puddled soil).

- Dry-DSR (primarily done for water saving) - Dry-DSR involves changing both land preparation and rice establishment methods (puddled transplanting to dry-direct seeding in unpuddled soil).

Dry-seeded rice involves growing rice in unpuddled and non-flooded (aerobic) soil conditions like maize and wheat. This option can help in saving water, energy, labour and time. Dry- seeded rice is expected to response (like maize) to changes in soil physical environment caused by deep tillage. Dry seeded rice (DSR) provides a gateway for advancing crop establishment to make better use of early season rainfall, and facilitates an increase in crop intensification in rice based systems (Tuong *et al*., 2000). However, DSR needs to be sown earlier, so the field is exposed to higher evaporative demand for a much longer period than a puddled transplanted field. However, (Bouman, 2001) claimed the potential water savings at the field level in upland rice due to less evaporation since there is no permanent ponded water layer, and the amount of water used for puddling is eliminated altogether. However, many researchers have found similar input water productivity (WPI+R) for both dry seeded and conventional PTR (Choudhury *et al*., 2007).

Cop Management Interventions to Enhance Water Productivity in Dry Seeded Rice

- Irrigation scheduling
- Tillage
- Mulching
- Cultivars
- Planting method

Irrigation Scheduling

Yadav *et al*., (2011) reported there was no irrigation water saving in DSR compared to PTR when the crop was irrigated daily. However, the irrigation input to DSR was lower than to PTR with in irrespective irrigation scheduling. DSR irrigated at 20 kPa soil water tension reduced the irrigation input by 30-35 % in comparison with puddeled 20 kPa in the field experiments.

Table 1: Effects of irrigation scheduling on yield of dry-seeded rice

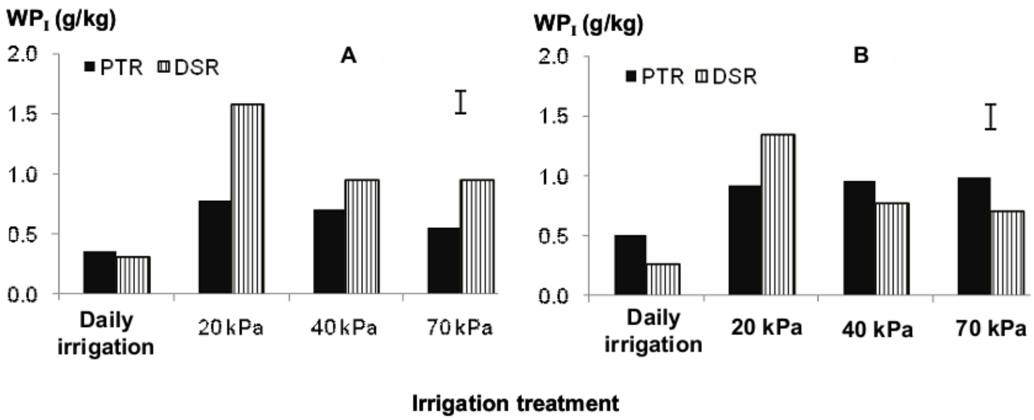
Irrigation scheduling	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
Daily	7.42	11.26	0.36
20 kPa	7.42	8.55	0.43
40 kPa	4.26	7.67	0.32
70 kPa	3.21	6.87	0.34

Grain yield of DSR with daily and 20-kPa irrigation was similar and significantly higher than the yield of all other treatments. The higher yields of DSR with daily and 20-kPa irrigation were largely due to higher panicle density and more florets per panicle, and to a lesser degree to higher grain weight (Yadav *et al*., 2011).

In both years, WP_I of DSR irrigated at 20 kPa was significantly higher than in all other treatments. In a year of above-average and relatively well-distributed rainfall, alternate wetting and drying resulted in very large irrigation water savings in both PTR and DSR.

An irrigation threshold of 20 kPa was the optimum in terms of maximizing grain yield, $WP_{I,}$ WP_{I+R}, and WP_{ET} of both PTR and DSR.

Irrigation water productivity of DSR-20 kPa was much higher than that of PTR-20 kPa due to a 30% to 50% reduction in irrigation input, while grain yield was maintained. Rice established with dry seeding was more sensitive to increasing the irrigation threshold beyond 20 kPa, resulting in lower grain yield, WP_I, WP_{I+R}, and WP_{ET} than for PTR at the same thresholds (40 and 70 kPa).



Yadav *et al.*, (2011)

Figure 1: Irrigation water productivity (WPi) as affected by establishment method and irrigation schedule in 2008 (A) and 2009 (B)

Tillage

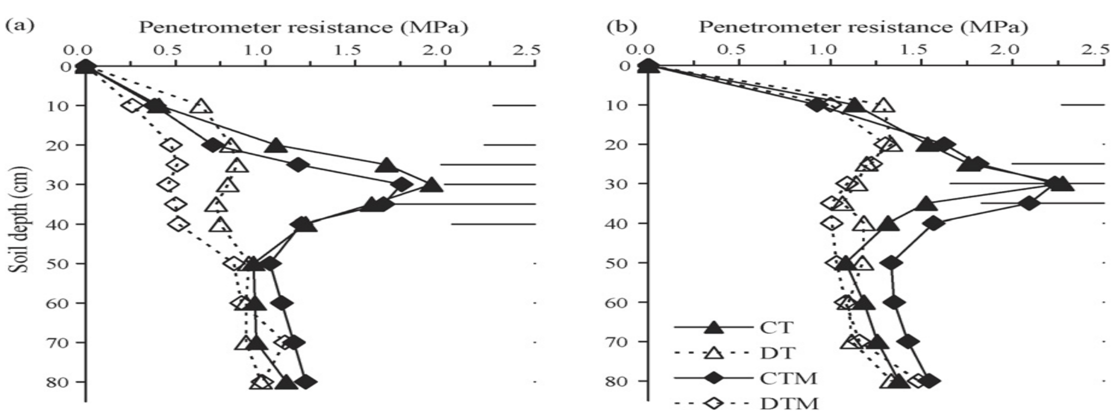
- Tillage affects crop growth by altering soil edaphic environment.
- Rice plants are unable to utilize soil water in the deeper layers because of shallower root system.
- Deep root development is advantageous for water extraction during drought in upland rice.
- Deep root proliferation encouraged by appropriate agronomic methods such as deep tillage (chiseling down to 30-35 cm depth followed by Conventional tillage).

Deep tillage with deep placement of manure induced deep root proliferation and higher nitrogen uptake, increasing biomass production, panicle number, and consequently enhanced the grain yield.

Table 2: Grain yield and yield components for conventional and deep tillage in upland rice

Water deficit upland	**Grain yield (t/ha)**	**Harvest index**	**Panicle number (m^{-2})**	**Spikelet number (Panicle^{-1})**	**Fertility (%)**
CT	3.8	0.34	224	98	83
DT	4.6	0.36	251	103	87

Kato et al., (2007)



Kato *et al.*, (2007)

Figure 2: Profiles of cone penetrometer penetration in soil in rainfed upland rice

CT- Conventional tillage, CTM- Conventional tillage with mulch DT- Deep tillage, DTM- Deep tillage with mulch

Table 3: Total root weight and Deep root weight under rainfed upland rice measured on 122 DAS

Treatments	Total root weight (TRW) g/m^2	Deep root weight (DRW) g/m^2
CT (Conventional tillage)	48.1	5.6
DT (Deep tillage)	42.2	11.2
CTM(Conventional tillage with mulch)	54.4	9.2
DTM (Deep tillage with mulch)	48.0	11.3

Kato et al., (2007)

Rice plants with deep tillage with deep manure application without mulch tended to have lower leaf water potential and higher diffusion resistance during draught, and negative effects on grain filling and harvest index.

When deep tillage with deep placement of manure was combined with mulching, enhanced the grain yield, suggesting their synergistic mechanisms for yield increase and stabilization. Deep root was referred to the root existing below 35cm depth.

Mulching

Mulch keep the soil moisture higher than without mulch even at reproductive stage, and it increased the yield to the greatest extent under the most favorable conditions with much rainfall before heading.

Table 4: Effect of mulch on soil evaporation (Es) and grain yield in rainfed upland rice

Treatments	Es (mm) 82 DAS	Es (mm) 100 DAS	Grain yield(t/ha)
CT (Conventional tillage)	2.3	2.2	4.7
CTM(Conventional tillage with mulch)	1.1	1.0	4.9

Kato et al., (2007)

Characteristics of Cultivars to Enhance Water Productivity in Dry-Seeded Rice

- Short duration rice cultivars
- Drought tolerance
- Modified root system (greater root penetration)
- Input responsive
- Lodging resistance
- Early vigor

Planting Methods

Table 5: Effects of planting methods on yield under direct seeded rice

Planting methods	Grain yield (t/ha)	Straw yield (t/ha)
Rotavator seeding	3.6	5.2
Zero till seeding	3.1	4.6
Direct sowing in prepared soil ((conventional)	3.8	5.8

Bazaya et al., (2009)

Study on effect of planting methods on soil properties, yield and NPK uptake by rice (*Oryza sativa* L.) under direct seeded condition reported that planting methods significantly influenced the physical, chemical and biological properties of soil. The highest grain and straw yields and N, P, K uptake was recorded in conventional seeding and was found significantly superior to zero till seeding but it remained at par with rotavator seeding.
Choudhary *et al.*, (2007) compare the yield, input water (rainfall and irrigation) use and water productivity of dry-seeded rice on raised beds and flat land with that of flooded transplanted and wet-seeded rice, and analyzed the effects of beds on the subsequent wheat crop.

Table 6: Effects of different crop establishment techniques on yields and water productivity of rice

Treatments	**IW (mm)**	**ET (mm)**	**Yield (t/ha)**	**WP_{ET} (kg/m^3)**	**WP_{IR} (kg/m^3)**
TPR	1592	840	5.47	0.65	0.34
WSR	1451	856	4.38	0.57	0.30
DSR	**1062**	**558**	**4.20**	**0.75**	**0.40**
RB	860	476	3.47	0.72	0.36

Choudhary et al., (2007)
TPR-Flooded transplanted rice, WSR-Flooded wet seeded rice, DSR- Direct seeded rice, RB-Direct seeded rice on raised beds; WP_{ET}, WP_{IR} refer to water productivity based upon evapotranspiration, irrigation & rainfall.

Rice yields on raised beds that were kept around field capacity were 32–42% lower than under flooded transplanted conditions and 21% lower than under flooded wet-seeded conditions. Water inputs were reduced by 32–42% compared with flooded rice, but could also be accomplished with dry seeding on flat land with the same water management.
Reduced water inputs and yield reductions balanced each other so that water productivity was comparable among most treatments. Wheat yield was 12–17% lower on raised beds than on flat land with conventional (20cm) row spacing. Neither wheat nor rice on raised beds compensated for the loss in rows by extra tillering or leaf growth at the edges of the rows.

Conclusion

Wet-DSR is primarily done for labor saving and for water saving Dry-DSR has emerged as a viable alternative. The various management interventions that reduce irrigation water amount and increase water productivity are urgently required in Dry-DSR. In dry-seeded rice water use efficiency and productivity are likely to improve if appropriate irrigation schedule, mulching, tillage, cultivars and planting methods are adopted.

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