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Land and water productivity of direct seeded rice in relation to differential irrigation scenarios in Indian Punjab

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Abstract

A field study was conducted in sandy loam soil to monitor the crop performance and irrigation water productivity of direct dry seeded rice under soil matric potential based intermittent irrigation at different growth stages. The treatments included four soil matric potential based irrigation scenarios viz 10-10-10, 10-20-10, 10-10-20 and 20-20-20 kPa at 3-leaf to panicle initiation (PI), PI to flowering and flowering to physiological maturity stages during 2011-12. The yield attributes viz panicle density, grains per panicle and thousand grain weight were statistically similar in all the treatments. The biomass and tiller density at different growth stages did not vary with differential irrigations. The grain and biomass water productivities, though higher during 2011 than in 2012, were statistically similar under different irrigation scenarios. Soil matric potential at 10 cm depth indicated sufficient drying of soil (>20 kPa) under the wettest (10-10-10 kPa) treatment and >40 kPa in the driest (20-20-20 kPa) treatment.

Keywords: Irrigation water productivity, soil matric potential, direct seeded rice

Introduction

Rice is an important target for irrigation water use reductions, because of its relatively large water requirements compared with other crops (Tuong and Bouman, 2003, Humphreys *et al.*, 2010). Rice is generally grown under puddled conditions mainly to reduce percolation losses and weed control. However, the puddling process besides consuming a substantial amount of irrigation water, results in subsurface compaction (Kukal and Aggarwal, 2003). The high water requirement of conventionally flooded puddled transplanted rice (PTR) has become a major threat to the sustainability of rice production due to over exploitation of ground water resources in Indo-Gangetic Plains (IGP), more so in the north-west IGP of India. A groundwater depletion rate of 4.0±1.0 cm per year was reported over the north-west Indian states of Rajasthan, Punjab and Haryana (Rodell *et al.*, 2009). Apart from the water depletion, the scarcity of labor for transplanting is increasingly being felt over the last ten years and is expected to aggravate further.

Direct dry seeded rice (DSR) is one such technique which can help to solve the issue of labor scarcity and is being advocated to save upon irrigation water. The DSR with intermittent irrigation could offer potential water savings at the field level due to reduced evaporation losses, intermittent irrigation and avoidance of puddling. However, it needs to develop optimum thresholds for irrigation scheduling to DSR. Soil matric potential-based irrigation scheduling has been shown to save upon irrigation water even in comparison to fixed-day intermittent irrigation at 2-day interval (Kukal *et al.*, 2005). No significant decline in grain yield has been observed with irrigation thresholds up to 16 kPa (Kukal *et al.*, 2005) in PTR or 20 kPa (Sudhir-Yadav *et al.*, 2011a) in DSR.

Studies in fine textured soils in the region (Sudhir-Yadav *et al.* 2011a) have reported similar grain yield of DSR and PTR with substantial savings in irrigation water (Sudhir-Yadav *et al.*, 2011b). However, the effect of DSR on water use and water productivity is not well understood in medium textured soils. The preliminary studies on water productivity of DSR in medium textured soils have not shown promising results with respect to crop performance and water productivity in the region. Sudhir-Yadav *et al.* (2011c) while simulating the irrigation effects on DSR observed that DSR if irrigated with lower soil matric potential at sensitive growth stages could help in increasing crop water productivity. The present study was thus undertaken in a sandy loam soil to monitor the crop performance and water productivity of DSR in relation to differential soil matric potential based irrigation scheduling at different growth stages.

Materials and Methods

A field experiment was carried out during 2011-12 at Punjab Agricultural University on sandy loam soil to monitor the performance and irrigation water productivity of direct dry seeded rice (DSR) under different irrigation

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scenarios. The study soil was slightly alkaline and low in soil organic carbon (Table 1). The site was under a rice-wheat cropping system for at least 5 years prior to establishment of the experiment and rice had been grown as DSR for last 3 consecutive seasons.

Table1. Soil properties at the experimental site

Depth (cm)	pH	EC (dS m^{-1})	SOC (%)	Bulk density (g cm^{-3})	Soil water content (%)		Sand (%)	Clay (%)
					FC	PWP		
0-15	8.27±0.08	0.29±0.10	0.29±0.07	1.43±0.06	17.1	7.6	78	17
15-30	8.44±0.16	0.21±0.04	0.26±0.02	1.53±0.04	19.3	8.8	65	20
30-45	8.36±0.05	0.14±0.01	0.17±0.02	1.50±0.02	22.1	10.8	58	25
45-60	8.31±0.05	0.13±0.01	0.21±0.11	1.47±0.03	25.6	12.7	52	28

The experiment was laid in randomized block design with 4 treatments. Each treatment was replicated thrice. Irrigation schedules based on soil matric tension of 10 and 20 kPa at three growth stages (3 leaf stage to PI, PI to flowering and flowering to physiological maturity) viz 10-10-10, 10-20-10, 10-10-20 and 20-20-20 kPa in plots of 72 m^2 size were evaluated for the rice productivity. The site was cultivated and laser leveled prior to establishment of the experiment. The DSR was sown on 7th and 4th June during 2011 and 2012, respectively and fertilized with 150 kg N/ha in four splits. All treatments received a basal fertilizer application of 67.5 kg P ha^{-1} as diammonium phosphate (DAP), 50 kg K ha^{-1} as muriate of potash (MOP) and 62.5 kg Zn ha^{-1} as zinc sulphate broadcasted prior to sowing. Weeds were controlled by applying a pre-emergence herbicide, Pendimethalin (Stomp 30% EC) was sprayed (2500 ml ha^{-1}). Bispyribac sodium (Nominee Gold 10% SC) and amine salt (2-4D) were used as a post emergence herbicide at the rate of 250 ml ha^{-1} and 500 g ha^{-1} respectively. In addition to chemical control, three hoeing were also performed to control the weeds. Insects and diseases were controlled by chloropyriphos (Chloroguard 20% EC) @ 50 g ha^{-1}, monocrotophos (Monocil 36%SL) @ 50.4 g ha^{-1} and propiconazole (Tilt 25%EC) @ 62.5 g ha^{-1} as recommended. To ameliorate iron deficiency, three sprays of ferrous sulphate ($FeSO_4$) were carried out at 46, 86 and 95 DAS. The quantity of irrigation water applied was measured using area velocity method. The crop was irrigated frequently to keep the soil near field capacity up to 3 leaf stage to avoid water deficit stress during crop establishment. Thereafter, the irrigations were scheduled as per the treatments using tensiometers installed 20 cm soil depth. Effective rainfall of 1097 mm and 422 mm were recorded during crop seasons of 2011and 2012 respectively (Figure 1). The rainfall was well distributed during 2011 (19 rainy days) than in 2012 (14 rainy days) during crop season having ≥ 10 mm rain. During 2011, about 400 mm of rain was recorded in a single day.

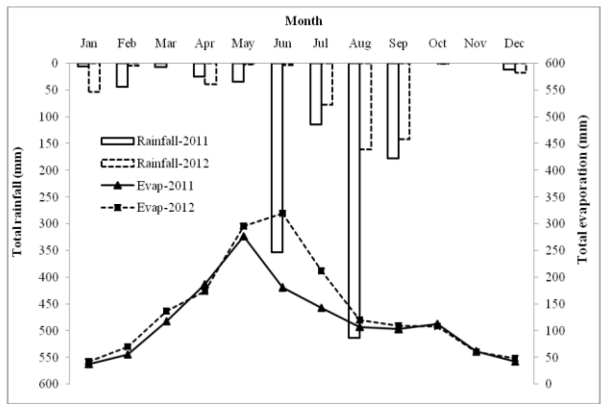


Figure 1: Rainfall and evaporation distribution during rice season in 2011-12

Results and Discussion

Crop performance

Panicle density, grains per panicle and thousand grain weight were statistically non-significant under all the irrigation scenarios except grains per panicle during 2012 which were significantly higher in 10-10-10, 10-20-10 and 10-10-20 kPa plots compared to 20-20-20 kPa. However, the difference was not reflected in the grain yield. Despite of the wettest possible irrigation treatment (10-10-10 kPa), the yield components did not significantly improve from that in 20-20-20 kPa treatment which earlier was shown to be optimum threshold for DSR in clay loam soil (Sudhir-Yadav *et al.*, 2011a, b). Thousand grain weight was higher during 2012 than during 2011, which seemed to be only yield parameter to contribute towards the grain yield which was higher during 2012 than in 2011 (Table 2).

Table 2: Yield components

Treatment (SMP-kPa)	Grains per panicle		1000 grain weight (g)		Grain yield (t/ha)	
	2011	2012	2011	2012	2011	2012
10-10-10	63	72	18.4	22.8	4.24	4.80
10-20-10	56	64	17.7	22.7	3.62	4.27
10-10-20	55	61	17.9	22.8	3.20	4.79
20-20-20	57	45	18.0	24.8	2.96	3.58
LSD (0.05)	NS	12.28	NS	NS	NS	NS

The tiller density (Fig. 2) did not show any significant differences among different irrigation treatments but were higher in 20-20-20 kPa (driest) plot during 2011 (Figure 2a) but in 2012 (Figure 2b) the trend reversed.

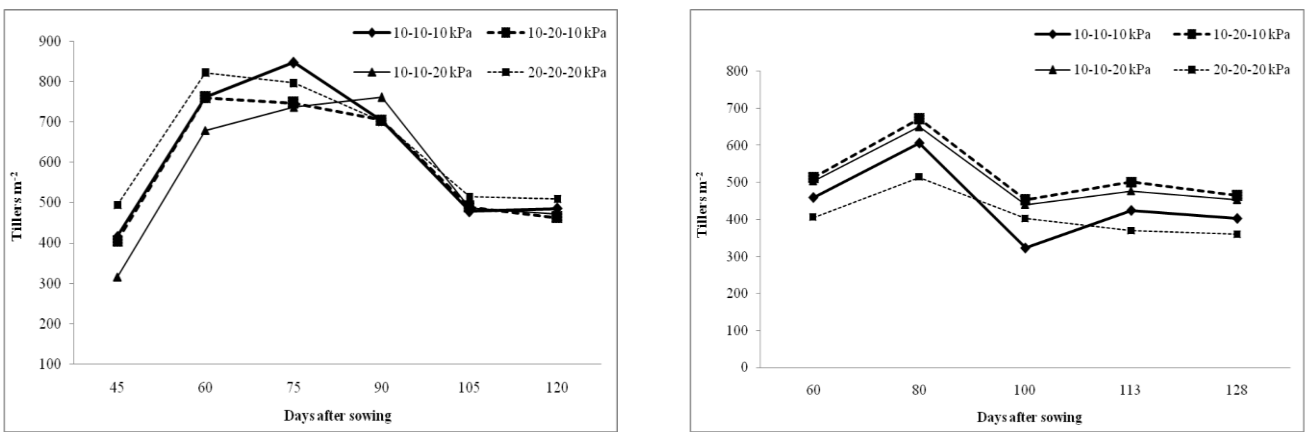


Figure 2: Periodic tiller density during (a) 2011 and (b) 2012 in relation to differential irrigation

The periodic biomass did not differ much till 105 DAS but it was sufficiently higher under 10-10-10 kPa treatment and was lowest in 20-20-20 kPa in 2011 (Figure 3a). However, during 2012 there were non-significant differences in biomass at 128 DAS, but still interestingly it was 20-20-20 kPa plots (Figure 3b). Since the rainfall during 2012 was poor, this might have resulted in lowest tiller density as well as biomass in 20-20-20 kPa (driest condition among all the treatments) plots in comparison to 2011 where it was other way round. This indicate that most frequent irrigation may be required for better DSR but still the crop performance was not at par with PTR.

Irrigation and total water inputs

The amount of irrigation water applied to the crop during 2012 was higher than that in 2011 (Figure 4a, b). However, the total input water to the crop was similar during both the years. The difference in the irrigation water amount applied during the two years was mainly due the differences in the rainfall during the corresponding years. Reducing the frequency of irrigation from 10-10-10 kPa to 10-20-10/10-10-20 kPa did not result in sufficient reduction in amount of irrigation water. However, further reduction in irrigation frequency to 20-20-20 kPa decreased amount of irrigation water by 31.8 and 12.1 percent during 2011 and 2012 respectively. This indicates that during harsh season with lower rain input, the difference in irrigation amount among different treatments decreases. Similar observations were made by Sudhir-Yadav *et al.* (2011a,b,c) in a clay loam soil.

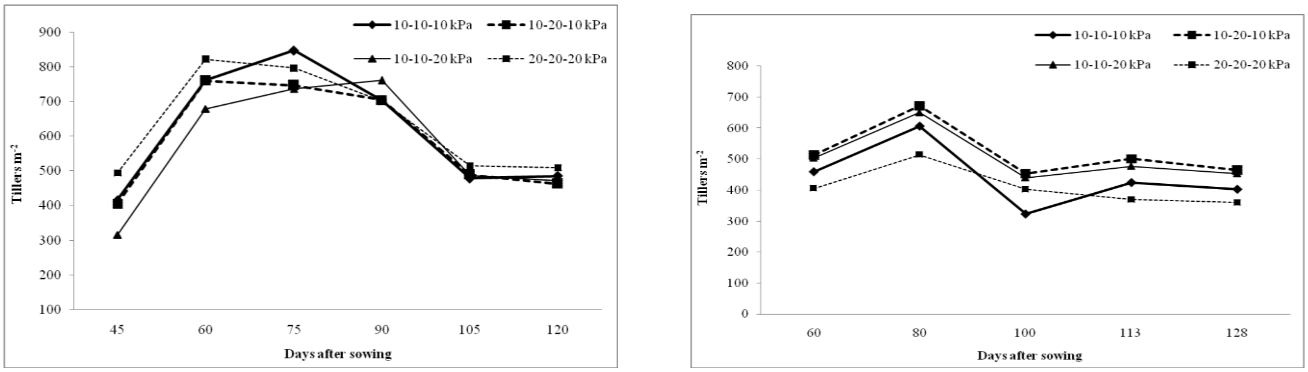
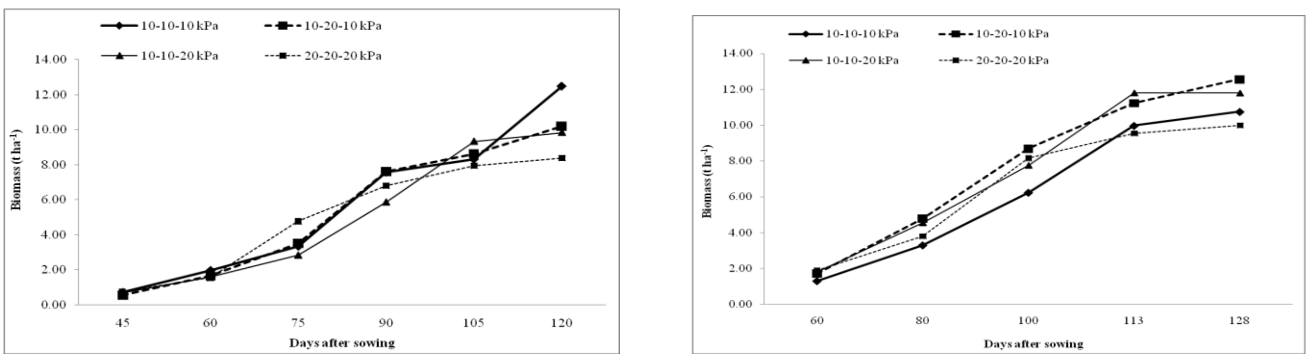
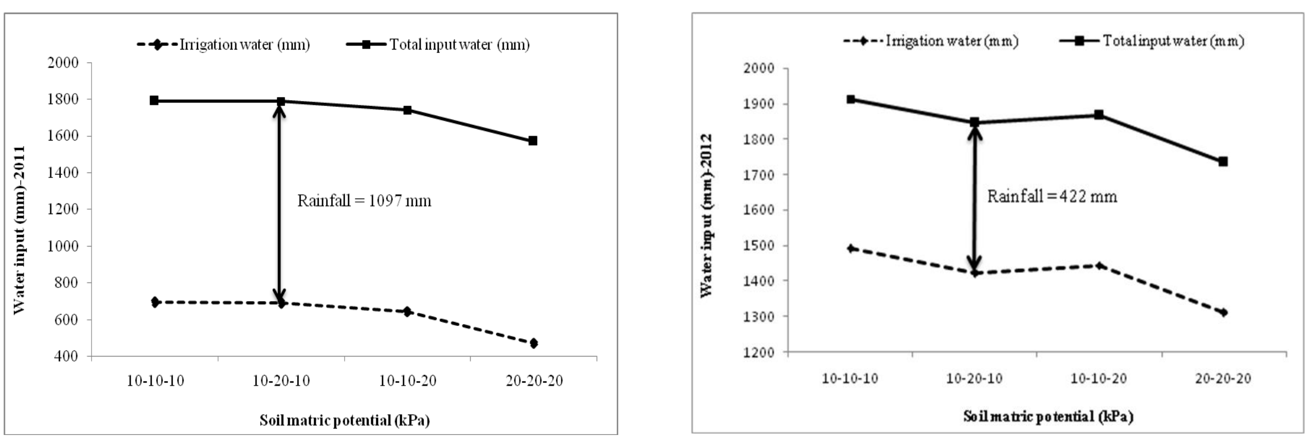


Figure 2: Periodic tiller density during (a) 2011 and (b) 2012 in relation to differential irrigation



(a) (b)

Figure 3: Periodic biomass during (a) 2011 and (b) 2012 in relation to differential irrigation



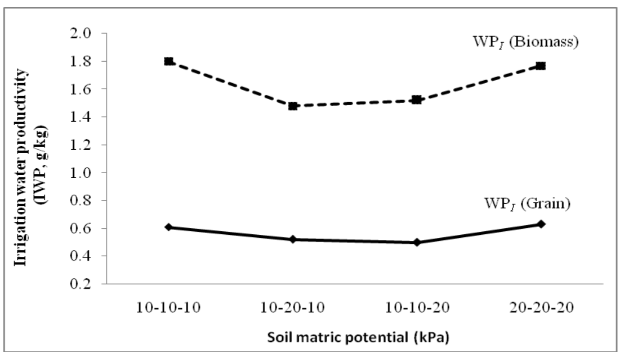
(a) (b)

Figure 4: Water input to the crop during (a) 2011 and (b) 2012 in relation to differential irrigation

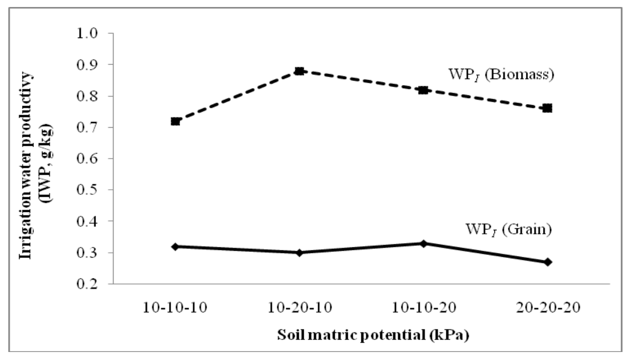
Irrigation water productivity (WP_I, g kg^{-1})

The irrigation water productivities expressed on basis of grain and biomass yield, during both the years of study were statistically similar under all the irrigation scenarios. However, both the irrigation water productivities were sufficiently higher during 2011 than during 2012 (Figure 5a, b) despite of the fact that grain yield was higher under all irrigation scenarios during 2012. It was mainly because of higher (1097 mm) and well distributed rainfall (19 rainy days) in 2011 crop season, compared to that in 2012 (422m and 14 rainy days).

The higher irrigation water productivity in DSR than in PTR was mainly because of the water required for puddling operations and that used for continuous flooding during first fortnight after transplanting as observed by Sudhir-Yadav *et al.* (2011b) in a clay loam soil. In the present study, the amount of water consumed per irrigation was higher (7.5-8.5 cm) than that in puddle soils which consumed lower amount of irrigation water per irrigation (Kukal *et al.*, 2009) due to lower infiltration rate of puddle soils. The infiltration rate of sandy loam soil had been shown to be 2-3 times higher than that in puddled soils (Kukal *et al.*, 2008).

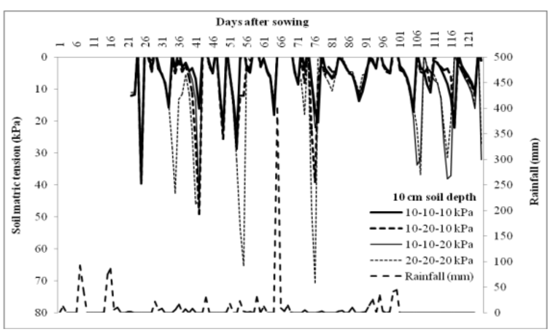


(a)

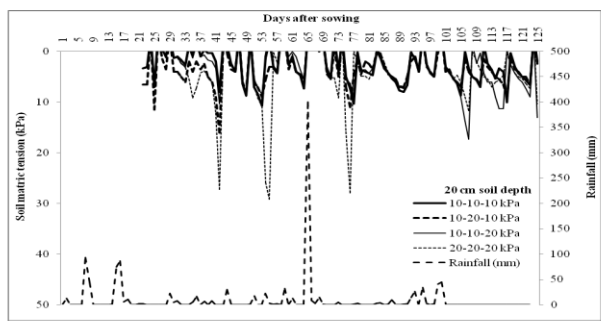


(b)

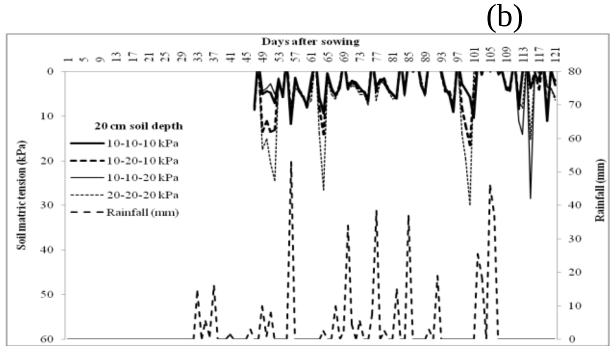
Figure 5: Grain and biomass irrigation water productivities during (a) 2011 and (b) 2012



(a)



(b)



(c)

Figure 6: Soil matric tension at (a) 10 cm, (b) 20 cm soil depth during 2011 and (c) 20 cm depth during 2012 under different irrigation scenarios

Periodic soil matric potential at different depths indicates sufficient soil drying at 10 cm both in 10-10-10 kPa (beyond 20 kPa) and 20-20-20 kPa (beyond 40 kPa) irrigation scenarios (Figure 6a). This indicates that despite of frequent irrigations, the soil dried very fast at 10 cm depth leading to the yield penalty and is being supported by Singh *et al*. (2015). Soil matric potential at 20 cm depth indicated frequent drying in the plots with 20-20-20 kPa irrigation scenario during both the years (Figure 6b, c). The sandy loam soil with higher hydraulic conductivity result in faster movement of water out of rice rhizo-shpere leading to water and nutrient stress in plants.

Conclusions

Our results indicated that the direct seeded rice did not perform well in sandy loam soil both from land and water productivity point of view. It was mainly due to higher weed pressure, iron deficiency, nematode infestation etc. Even the wettest irrigation scenario (10-10-10 kPa) throughout the crop growth season did not help improve the grain yield of direct dry seeded rice. At the same time decreasing the irrigation frequency (20-20-20 kPa) decreased grain yield compared to the most frequent irrigation scenario (10-10-10 kPa).

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