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Irrigation and Deep Tillage Effects on Water Productivity of DRY-seeded Rice (*Oryza Sativa* L.)

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Abstract

An alarming fall in groundwater table in North-West India demands a major shift from traditional method of rice cultivation to direct seeding of rice. Average fall in water table in central region of the state has been more than 0.75 m year^{-1} in the last decade (Minhas et al 2010 and Humphreys et al 2010) that threatens sustainability of rice production. Dry-seeded rice has emerged as a viable option to save water, labour, energy and time. The various management techniques that reduce irrigation water amount and labor requirement with sustaining yields are urgently required. Proper irrigation scheduling in relation to tillage was adopted to improve water productivity in dry-seeded rice and reduce ground water depletion. A field experiment was conducted at the research farm of the Department of Soil Science, Punjab Agricultural University, Ludhiana, during Kharif 2012 to study the interactive effects of irrigation and deep tillage on water productivity of dry-seeded rice. The treatments included two irrigation regimes - IW: CPE ratio of 2.4 ($I_{2.4}$) and 1.2 ($I_{1.2}$) in main plots and two tillage regimes (deep tillage and conventional tillage) in subplots. Water productivity was higher in $I_{1.2}$ than $I_{2.4}$ because higher numbers of irrigation were applied in higher irrigation ratio as compared to lower irrigation ratio. DT was observed to have lower soil penetration resistance, higher root biomass, number of grains per panicle and thousand grain weight and yield (5.9 t ha^{-1}) than CT (5.1 t ha^{-1}). The interactive effects of irrigation and tillage were also observed that DT $I_{1.2}$ has highest water productivity followed by DT $I_{2.4,}$ CT $I_{1.2}$ and CT $I_{2.4}$ treatments.

Keywords: Irrigation, Deep tillage (DT), Water productivity, Dry-seeded rice.

1. Introduction

Rice (*Oryza sativa* L.) is an important cereal food for more than half of the global population. About 55 per cent of the rice area is irrigated that accounts for 75 percent of the rice production in the world (Bouman 2001). Rice is a major user of freshwater accounting for approximately 50 per cent of the total diverted fresh water in Asia. The irrigated rice-wheat (RW) cropping system of north-west India is fundamental to India's food security (Timsina and Connor 2001). Productivity and profitability of rice is high under alluvial irrigated tracts and groundwater is the primary source for irrigation. Flood-irrigated rice utilizes two or three times more water than other cereal crops such as maize and wheat. However, large amount of water input in rice culture has led to over-exploitation of groundwater as indicated by alarming fall in water table. This fall has resulted in increased energy requirement and cost of pumping groundwater, increased tube well installation cost and deteriorated the ground water quality (AICRP 2009, Kamra *et al* 2002). Thus, there is a need to explore alternate techniques that can sustain rice production and are resource conservative.

On the face of global water scarcity and escalating labour rates, when the future of rice production is under threat, direct-seeded rice offers an attractive alternative (Farooq *et al* 2011). Dry seeding of rice with subsequent aerobic soil conditions avoids water application for puddling and maintenance of submerged soil conditions, and thus reduces the overall water demand (Bouman 2001, Sharma *et al* 2002). As soil water dynamics in dry-seeded rice is different from that of puddle transplanted rice, this is likely to affect water and nutrient uptake, and ensuing growth and crop yields. Dry-seeded rice is expected to respond (like maize) to changes in soil physical environment caused by deep tillage resulting in improved crop productivity. Tillage under intensive cropping system has the additional challenges of ensuring high water use, nutrient use and energy use efficiencies through deeper and denser crop rooting (Gajri *et al* 2002).

2. Materials and METHODS

2.1. Experimental details

The field experiment was conducted during *kharif* season of 2012 at research farm of the Department of Soil Science, Punjab Agricultural University, Ludhiana, (30°54' N, 75°58' E, 247 m above sea level), Punjab, India. The experiment was laid out in three replicates with two irrigation regimes (based on irrigation water to cumulative pan evaporation ratios) of $I_{2.4}$ and $I_{1.2}$ in combination with two tillage regimes (conventional tillage and deep tillage). The rice growing season extends from June to October, the monthly mean air temperature ranged from 23.9 to 33.9°C. Both maximum and minimum temperatures were found to fluctuate throughout the crop growing season. Monthly maximum temperature of 40.6°C was recorded in the month of June and minimum temperature of 16.2ºC was recorded in the month of October. Total rainfall received during the cropping season was 380 mm with maximum rain of 160.4 mm was recorded in the month of August and higher evaporation of 315 mm was recorded in the month of June. The soil of experiment site contained average of 72.5 per cent sand, 15.8 per cent silt and 11.8 per cent clay. The soil is slightly alkaline (pH 7.9-8.1). The experimental soil was low in organic carbon (0.38%) and $KMnO4$ extractable N (152.1 kg ha^{-1}), medium in available P (13.7 kg ha^{-1}) and medium in available K (145 kg ha^{-1}).

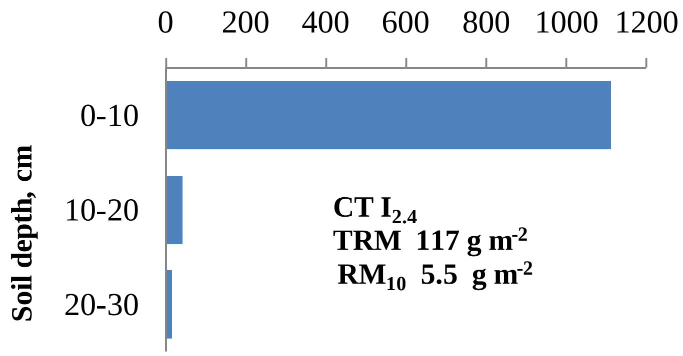
Table 1: Physico-chemical properties of the soil profile.

Soil depth (cm)	Sand	Silt	Clay	pH	EC (ds/m)	Bulk density (g/cm^3)
0-15	78	13	9	8.0	0.28	1.50
15-30	76	14	10	8.1	0.20	1.45
30-60	68	18	14	7.9	0.18	1.55

3. Results and Discussion

3.1 Root growth

Among tillage and irrigation regimes, root mass density was highest in CT $I_{2.4}$ followed by DT $I_{2.4}$, CT $I_{1.2}$ and DT $I_{1.2}$. It varied from 1111, 919, 909 and 844 µg cm^{-3}. While in 10-20 cm soil layer root mass density was highest in DT $I_{2.4}$ followed by CT $I_{1.2}$, DT $I_{1.2}$ and CT $I_{2.4}$. Root mass density of subsurface layer (20-30 cm) was greatly affected by DT and root mass density of subsurface layer was highest in DT $I_{1.2}$ followed by CT $I_{1.2}$, DT $I_{2.4}$ and CT $I_{2.4}$. It varied from 43, 16, 15 and 14 µg cm^{-3}.



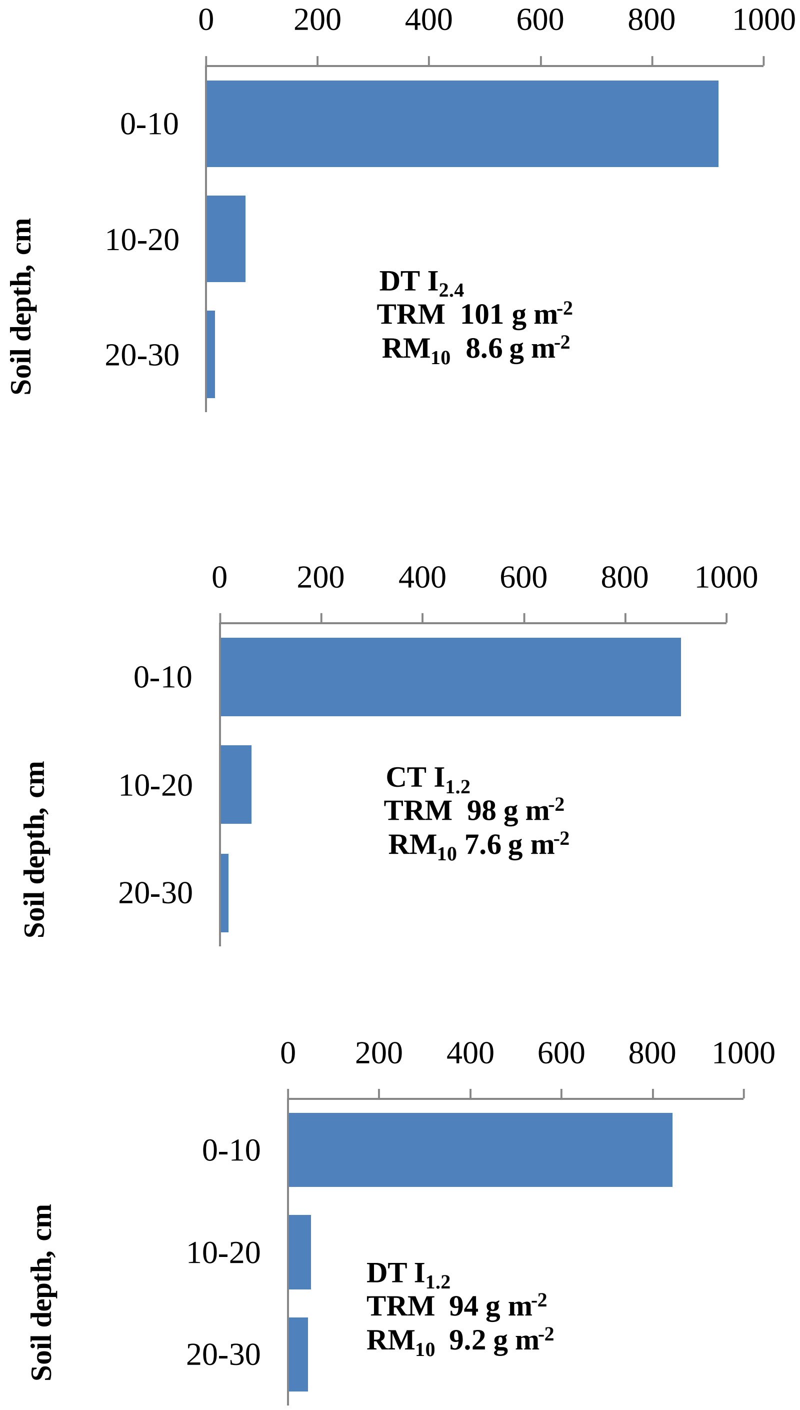


Fig. 1: Interactive effect of irrigation and tillage on root mass density.

Root mass below 10 cm of soil profile (RM10) and RM 10 was greatly enhanced by DT under water deficit conditions in both the cultivars and the effect of DT was more in PR115 as compared to PR114. Among tillage and irrigation regimes, RM10 was highest in DT $I_{1.2}$ followed by DT $I_{2.4}$, CT $I_{1.2}$ and in CT $I_{2.4}$ in PR114 and varied from 9.2, 8.6, 7.6 and 5.5 g m^{-2}. In PR115, RM10 was highest in DT $I_{1.2}$ followed by DT $I_{2.4}$, CT $I_{2.4}$ and in CT $I_{1.2}$ and varied from 9.7, 9.4, 8.8 and 4.2 g m^{-2}, respectively.

3.2 Water use efficiency

Effect of irrigation and tillage regimes on water use efficiency in relation to cultivars is presented in **Table 2**. Among tillage and irrigation regimes, highest irrigation and total water use efficiency was observed in DT $I_{1.2}$ followed by DT $I_{2.4}$, CT $I_{2.4}$ and lowest in CT $I_{1.2}$ and irrigation water use efficiency varied from 5.09, 4.47, 3.86 and 3.80 kg ha^{-1} $mm^{-1.}$ Higher water use efficiency in DT was probably due to increased grain yield through enhancing water and nutrient uptake from deeper layers under water deficit conditions. Shekara *et al* (2010) also reported that lesser irrigation water to cumulative pan evaporation ratio leads to higher water use efficiency and found that irrigation scheduled at $I_{1.0}$ showed higher water use efficiency (5.21 kg ha^{-1} mm^{-1}).

Table 2: Effect of irrigation and tillage regimes on water use efficiency of dry-seeded rice.

Irrigation and tillage regimes	CT $I_{2.4}$	DT $I_{2.4}$	CT $I_{1.2}$	DT $I_{1.2}$
Water use efficiency (Kg $ha^{-1}mm^{-1}$)	3.86	4.47	3.80	5.09

4. Conclusion

Root mass density in the surface (0-10 cm) layer was higher in CT $I_{2.4}$. While in deeper (20-30 cm) soil layer root mass density was higher in DT $I_{1.2}$. Among the irrigation and tillage regimes, highest water use efficiency was observed in DT $I_{1.2}$ treatments. In general with higher irrigation water, water use efficiency was decreased. DT follows the same trend but in CT water use efficiency was increased with increasing irrigation water.

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