Irrigation water productivity of rice grown with resource conservation technologies

S S Kukal[A], E Humphreys[B], S Yadav[C] and Yadvinder-Singh[A]

[A]Department of Soils, Punjab Agricultural University, Ludhiana, India, Email sskukal@rediffmail.com

[B]Internatinal Rice Research Institute (IRRI), Los Banos, Philippines, Email e.humphreys@cgiar.org

[C]The University of Adelaide, South Australia, Email sudhir.yadav@adelaide.edu.au

Abstract

Rice being one of the biggest users of world's developed fresh water resources, the agricultural scientists are facing a big challenge to improve its irrigation water productivity (WP_{IW}) so as to arrest the declining surface and ground water resources. Different resource conservation technologies (RCTs) are being developed and evaluated for their suitability both in submerged and aerobic system of rice production. This paper highlights the irrigation water use when practising the resource conservation technologies under different irrigation scenarios. The intermittent irrigation scheduling on the basis of soil matric tension (16 kPa at 20 cm depth) could save irrigation water by 30%. Growing of puddle transplanted rice (PTR) on raised beds does not help save irrigation water when similar irrigation schedules are followed in both in direct seeded rice (DSR) and PTR with full furrow-depth of irrigation water. Applying water with half furrow depth could help in improving irrigation water productivity. The water balance for direct-seeded rice needs to be computed under differential irrigation scenarios to achieve highest irrigation water productivity.

Key Words

Dry-direct seeded rice, intermittent irrigation, raised beds, soil matric potential.

Introduction

Changing global climatic patterns coupled with declining surface and ground water resources (Hira 2009) have put agriculture on the back foot. The most densely populated Asian countries consume and grow staple rice mainly under submerged conditions (Kukal and Aggarwal 2003) leading to its lower irrigation water productivity (WP_{IW}) (Humphreys *et al.* 2007). Since rice is one of the biggest users of world's developed fresh water resources (Tuong and Bouman 2003), the agricultural scientists are facing a big challenge to improve its WP_{IW} so as to check the decline of surface and ground water resources. Different resource conservation technologies (RCTs) are being developed and evaluated for their suitability both in submerged and aerobic system of rice production (Kukal *et al.* 2005; Humphreys *et al.* 2008). However, whether these RCTs really help save irrigation water is a point of debate, particularly when comparisons are made between similar irrigation schedules in rice grown with RCTs and conventional systems. For example rice grown under unpuddled conditions may consume higher irrigation water, if irrigated with the similar schedule as in puddled system. Thus irrigation needs to be rescheduled for different RCTs particularly when shifting from anaerobic system to aerobic system.

This paper aims to highlight the irrigation water dynamics in rice grown with different water conservation techniques viz. optimum transplanting time, intermittent irrigation at fixed day interval and more precisely at an optimum soil matric potential (SMP), furrow system of irrigation with rice grown on raised beds (fresh and permanent) and direct dry-seeded rice in medium textured soils.

Materials and methods

Soil matric potential based irrigation

The scheduling of irrigation intermittently at an interval of 2-d was compared with soil matric tension based irrigation (16 kPa at 20 cm depth) in rice raised as described above. These techniques were compared with the farmers' practice of continuous flooding at least for first 50-60 days. The soil matic potential was measured with locally fabricated vacuum gauge tensiometer.

Furrow irrigation in raised beds

Field experiments were carried out in Punjab, India, during 2002-2006 to compare irrigation water use and productivity of transplanted rice and drill-sown wheat on fresh and permanent beds and conventionally tilled flats. The experiments were conducted on deep alluvial sandy loam and loam (Ustochrept) soils in small replicated plots and in large farmer field blocks. The same irrigation scheduling rules were applied to beds and flats, for respective crops. In rice, this involved daily irrigation for the first two weeks after transplanting, followed by irrigation 2 d after the floodwater had dissipated from the surface of the flat plots or furrows. The rice crop was transplanted on 30 cm wide raised beds (both permanent and fresh beds) with furrow (37.5 cm) in between, prepared with a bed planter. The 30-d old seedlings were transplanted in the centre of the slope of the raised beds. The fresh beds were prepared afresh every time after knocking down the previous beds, whereas the permanent beds were not knocked down. These were reshaped before the sowing/ transplanting of the crops. The rice grown on raised beds was compared with the conventional puddled transplanted rice on flats for its irrigation water productivity with different irrigation schedules.

Results

Soil matric potential based irrigation

The most common method of irrigation in northwestern India is through alternate wetting and drying with a fixed irrigation interval, irrespective of soil type and climatic demand resulting in over-irrigation or under-irrigation under different soil and weather situations. Soil matric potential may be an ideal criterion for irrigation, since variable atmospheric vapour pressure deficit, soil texture, cultural practices and water management affect rice irrigation water requirements. The grain yield of rice remained unaffected up to soil moisture suction of 16±2 kPa each year (Table 1). Increasing soil matric suction to 20±2 and 24±2 kPa decreased rice grain yield non-significantly by 0–7% and 2–15%, respectively, over different years compared to the recommended practice of the 2-day interval for scheduling irrigation. Irrigation at 16±2 kPa soil matric suction helped save 30–35% irrigation water compared to that used with the 2-day interval irrigation.

Table 1. Performance of paddy crop and consumption of irrigation water in relation to soil matric tension based irrigation scheduling

Soil moisture tension (kPa)	Paddy yield (t/ha)	Irrigation water use (cm)	Irrigation water saving (%)
10 ± 2	6.44	111.8	24.6
16 ± 2	6.40	102.3	31.0
20 ± 2	6.21	89.5	39.6
24 ± 2	5.61	80.0	46.1
2-d fixed interval	6.43	148.3	--

Furrow irrigation in raised beds

Raised beds have been proposed for rice-wheat (RW) cropping systems in the Indo-Gangetic Plains as a means of increasing irrigation water productivity, among many other potential benefits. The amount of irrigation water applied to rice on permanent beds and puddled transplanted rice (PTR) was similar in the small plots on the sandy loam. However, on the loam, irrigation applications to the permanent beds were always higher than the puddled plots, by 16 to 21%. Over 4 years, WP_{IW} of transplanted rice on permanent beds decreased with time on both soils, mainly due to declining grain yield as the beds aged (Figure 1). Irrigation applications to fresh beds were lower than to the puddled flats (by 11% on the sandy loam, and 20-24% on the loam) while yields were only 7 and 15% lower, resulting in similar WP_{IW} on fresh beds and PTR. Reducing irrigation application from full-furrow to half-furrow depth in the farmers' field reduced the irrigation amount on both permanent and fresh beds by 40-50%, but also reduced yield by about 20% (Figure 2).

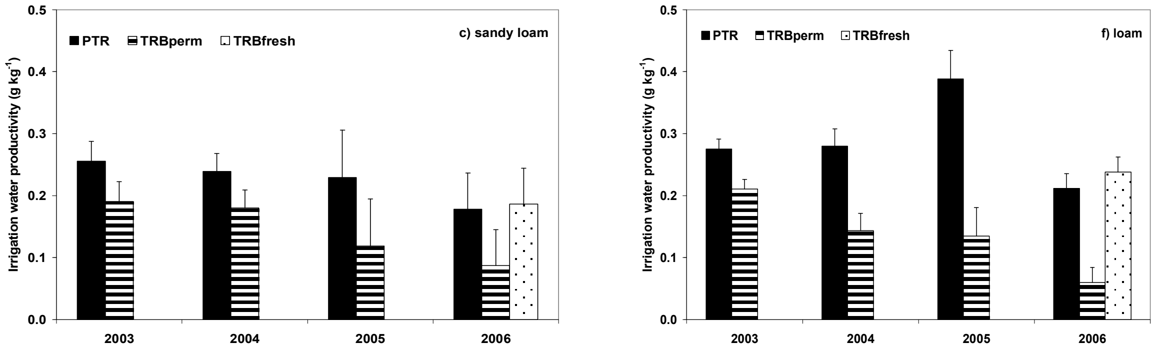

Figure 1. Irrigation water productivity of rice on permanent and fresh raised beds in small replicated experimental plots of (a) sandy loam and (b) loam

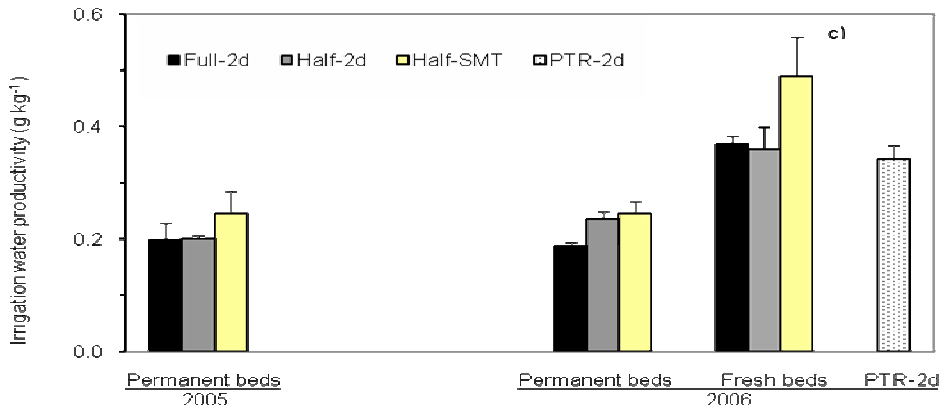

Figure 2. Irrigation water productivity of rice on permanent and fresh raised beds in farmers' scale field plots in loam

Conclusion

The studies indicate that the rice crop to be grown with resource conservation technologies can help save irrigation water provided the irrigation scheduling is re-worked for these techniques. Secondly the intermittent irrigation at a fixed time interval is not a feasible practice particularly during present day situation when the climate is becoming so uncertain. Thus the use of soil matric potential as a tool to schedule irrigation is a best bet in saving irrigation water as it indicates most precisely the irrigation time. Thus for each resource conservation technology to grow rice crop, the water balance parameters need to be worked out under different soil and climatic scenarios as a pre-requisite to decide upon the most efficient irrigation scheduling.

References

Hira GS (1996) Evaporation of rice and falling water table in Punjab. In 'Proceedings of International Conference on Evapotranspiration and Irrigation Schedulingheld at Texas, USA'. Nov. 3–6. (Eds. CR Camp, EJ Sadler, RE Yoder) pp.579–584. (American Society of Agricultural Engineers, USA).

Hira GS (2009) Water management in northern states and food security of India. *Journal of Crop Imporvement* **23,** 136-157.

Humphreys E, Masih I, Kukal SS, Turral H, Sikka A (2007) Increasing field scale water productivity of rice-wheat systems in the Indo-Gangetic Basin. In 'Science, technology, and trade for peace and prosperity' Proceedings of the 26th International Rice Research Conference, 9-12 October 2006, New Delhi, India. (Eds PK Aggarwal, JK Ladha, RK Singh, C Devakumar, B Hardy) pp. 321-341. (Los Baños (Philippines) and New Delhi (India): International Rice Research Institute, Indian Council of Agricultural Research, and National Academy of Agricultural Sciences. Printed by Macmillan India Ltd).

Humphreys E, Kukal SS, Amanpreet-Kaur, Thaman S, Yadav S, Yadvinder-Singh, Balwinder-Singh, Timsina J, Dhillon SS, Prashar A, Smith DJ (2008) Permanent beds for rice-wheat in Punjab, India. Part 2: water balance and soil water dynamics. In 'Permanent beds and rice-residue management for rice-wheat systems in the Indo-Gangetic Plain', Proceedings of a workshop held in Ludhiana, India, 7-9 September 2006. (Eds E Humphreys, CH Roth) pp. 37-61. Proceedings No. 127. (ACIAR Australian Centre for International Agricultural Research, Canberra, Australia). Available at http://www.aciar.gov.au/publication/term/18

Kukal SS, Aggarwal GC (2003) Puddling depth and intensity effects in rice-wheat system on a sandy loam soil. I. Development of subsurface compaction. *Soil and Tillage Research* **72,** 1-8.

Kukal SS, Hira GS, Sidhu AS (2005) Soil matric potential-based irrigation scheduling to rice (*Oryza sativa*). *Irrigation Science* **23**, 153-159.

Sudhir-Yadav (2003) Soil water dynamics in dry-seeded and puddle-transplanted rice. Proceedings, 19th World Congress of Soil Science.

Tuong TP, Bouman BAM (2003) Rice production in water scarce environments. In 'Water Productivity in Agriculture: Limits and Opportunities for Improvement'. (Eds JW Kijne, R Barker, D Molden) pp. 53–67. (CABI Publishing, Wallingford, UK).