Indian Journal of Agricultural Sciences **92** (2): 231–5, February 2022/Article
https://doi.org/ 10.56093/ijas.v92i2.122227

Tensiometer based irrigation scheduling in wheat (*Triticum aestivum*) in middle Indo-Gangetic plains

PREM K SUNDARAM[1], SANJEEV KUMAR[1]*, SHIVANI[1], UJJWAL KUMAR[1] and SURAJIT MONDAL[1]

ICAR-Research Complex for Eastern Region, Patna, Bihar 800 014, India

Received: 23 June 2020; Accepted: 31 August 2021

ABSTRACT

The most common method of irrigation in eastern India is through tube wells with a fixed irrigation interval, irrespective of the 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 soil texture, cultural practices and water management affect wheat irrigation water requirements. The present study deals with the effect of tensiometer based irrigation scheduling on crop productivity of wheat. The experiment was laid out in factorial randomized block design (RBD) with two factors, viz. soil moisture potential at three levels of 20, 35 and 50 kPa and tensiometer depth of 20, 35 and 50 cm under furrow irrigated condition at ICAR-Research Complex for Eastern Region, Patna during 2013–16. Tensiometer readings were recorded on a daily basis and irrigation was applied accordingly. The highest wheat yield (4.1 t/ha) was obtained when irrigation was applied at 35 kPa at 20 cm depth. The highest water productivity of 1.809 kg/m^3 was achieved under deficit irrigation (8.87 cm) with least grain yield (2.6 t/ha). Irrigation scheduling based at a pressure of 35 kPa at 20 cm or 20 kPa at 50 cm depth of tensiometer resulted in a significantly higher yield of wheat. Further field and modelling studies are needed to extrapolate the findings to a broader range of seasonal and crop conditions which will help in developing guidelines to assist farmers to schedule irrigation in wheat.

Keywords: Irrigation scheduling, Tensiometer, Water productivity, Wheat, Yield

Rice-wheat cropping system is responsible for decline soil health and underground water table in South-Asia. This system is labour, water, capital and energy-intensive. (Bhatt *et al.* 2016a). Indo Gangetic Plain region of India has Rice-Wheat Cropping system spread over a vast area spanning from Punjab in the Northwest to East up to West Bengal. However, a significant obstacle to boost crop yield is the availability and efficient use of water. Improvements in crop water productivity have the potential to improve both food security and water sustainability in many parts of world (Brauman *et al*. 2013). Different technologies, viz. laser leveler, zero tillage, short-duration cultivars, irrigation scheduling, alternate wetting and drying method of irrigation etc. have already been claimed for improving the water productivity of the crop. Irrigation scheduling is a planning decision which ensures that water is consistently available to plant and is applied according to crop requirements. Tensiometer based irrigation scheduling will help a lot in improving water productivity by applying irrigation when it is needed (Bhatt *et al.* 2016b). In wheat, farmers often apply irrigation based on visual observations of crop or soil appearance. However, these approaches don't take into account the soil water availability, which can vary depending on the soil type, crop growth rate, root distribution, evaporative demand and other management factors. Hence, crops may be stressed at some times and over-irrigated at others. Farmers tend to over-irrigate, applying 5–6 irrigations to wheat. With scheduling of irrigations according to plant available water, there is potential to save 1–3 irrigations (Yadav *et al.* 2013). Scheduling irrigation of wheat, based on soil water tension can help in increasing irrigation water productivity by avoiding water deficit stress and over-irrigation. Current irrigation scheduling guidelines for wheat in north-west India are based on growth stage or cumulative pan evaporation. They do not take into account the real-time availability of water in soil profile (Singh *et al.* 2011, Vashisht 2019). Therefore, experiments were conducted to evaluate the effects of irrigation threshold and measurement depth on wheat yield, irrigation water use and water productivity.

[1]ICAR Research Complex for Eastern Region, Patna, Bihar.
*Corresponding author email: shiv_sanjeev@yahoo.co.in

MATERIALS AND METHODS

A field experiment to investigate the effect of soil moisture potential on growth, yield and water productivity of wheat was conducted during 2013–16 at the ICAR Research Complex for Eastern Region, Patna (25°34'N, 85°03'E) Bihar. Total annual rainfall varied between 700–1053 mm during 2015 and 2016. The average amount

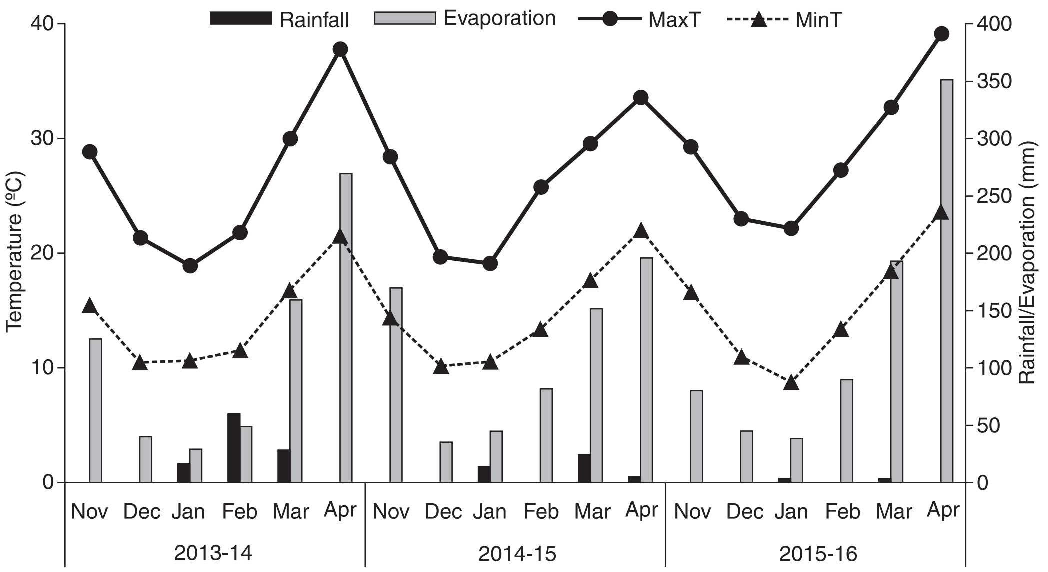

Fig 1 Weather parameters during *rabi* (2013–16)

of rainfall received during the cropping period (November-April) was 717 mm (Fig 1). The monthly maximum and minimum temperatures during the study period ranged from 18.9–39.1°C and 8.7–23.5°C, respectively. The soil was non-saline and silty clay in texture (16.8, 41.8 and 41.4% of sand, silt and clay, respectively) in plough layer. Bulk density was 1.34 g/cm^3 in the top soil. The soil had neutral *p*H (7.4) with medium soil organic carbon content (0.65%). The experiment was laid out in a factorial randomized block design. Two factors, viz. soil moisture potential (p_i) at three levels of 20, 35 and 50 kPa and tensiometer depth (d_i) at three levels of 20, 35 and 50 cm were replicated thrice.

Tensiometer consists of a porous ceramic cup tip connected to a plastic tube of desired length which is buried in the active root zone to measure the negative pressure arising from water depletion in root zone due to evapotranspiration (Kukal *et al.* 2014). Michael (2012) reported the advantage of tensiometers compared to volumetric soil moisture sensors; they are relatively inexpensive and the vacuum gauge can be read by the farmer. A hole was made in the soil up to 20, 35 and 50 cm depth with a diameter slightly larger than that of the tensiometer tip. Before lowering the tensiometer into the hole, the soil-water slurry was put into the hole to ensure soil-tensiometer tip contact. The tensiometers (Irrometer make) were installed mid-way between two plant rows at a distance of 0.5 m from the edge of the plot. The plants surrounding the tensiometers were representative of the plants in the whole plot. Readings were taken keeping a distance from the plots so that footprints were not stamped near the tensiometers. The size of the experimental plot was 12 m × 5 m. The nine irrigation treatments were: T_1–irrigation when soil moisture potential is 20 kPa at 20 cm tensiometer depth (p_1d_1), T_2–irrigation when soil moisture potential is 35 kPa at 20 cm tensiometer depth (p_2d_1), T_3–irrigation when soil moisture potential is 50 kPa at 20 cm tensiometer depth (p_3d_1), T_4–irrigation when soil moisture potential is 20 kPa at 35 cm tensiometer depth (p_1d_2), T_5–irrigation when soil moisture potential is 35 kPa at 35 cm tensiometer depth (p_2d_2), T_6–irrigation when soil moisture potential is 50 kPa at 35 cm tensiometer depth (p_3d_2), T_7–irrigation when soil moisture potential is 20 kPa at 50 cm tensiometer depth (p_1d_3), T_8–irrigation when soil moisture potential is 35 kPa at 50 cm tensiometer depth (p_2d_3), T_9–irrigation when soil moisture potential is 50 kPa at 50 cm tensiometer depth (p_3d_3).

Wheat variety HD2733 was sown during *rabi* 2013–16. Rice-wheat cropping system was practiced since 2009 in the plot and the previous crop grown was rice. Wheat was sown by seed drill in tilled field condition. A seed rate of 100 kg/ha was used at a sowing depth of 3–5 cm with row spacing of 20 cm. Sixty kg of N + full P and K (60 kg of each) were applied as basal + 20 kg of N at CRI stage + 20 kg of N after 45 DAS (jointing stage) and 20 kg of N at booting stage. Gravimetric soil water content was determined for the samples collected at depth intervals of 0–15, 15–30 and 30–50 cm from the top. Volumetric water content was determined from gravimetric water content and bulk density (Sevostianova *et al.* 2015). One common irrigation at 21 DAS was provided to all treatments. Tensiometer readings were taken daily and crop was irrigated whenever 2 out of 3 replicates had reached irrigation threshold tension. Plots were irrigated individually according to the pressure readings of tensiometer. For example, 20 kPa pressure treatments were irrigated when the needle of tensiometer moved beyond 20 kPa. Each irrigation was of 2.5 cm depth. At each irrigation, water was added until the plot was ponded to a depth of 2.5 cm. Plots were irrigated one at a time, and the volume of water added to each plot was recorded.

Plant density was measured in five rows (1 m long) at two locations in each plot after complete emergence, just before first irrigation. The uniformity of establishment was determined as the coefficient of variation of the plant number in individual rows. Tiller and spike counts were counted at two fixed locations (5 rows × 1 m) in each plot every two weeks throughout the season. At maturity, grain and straw yields were determined on an area of 15 m^2 in the middle of each plot by manually harvesting and mechanically threshing the samples. Total air-dried weight of grain and straw was measured in the field using a digital spring balance, and grain and straw moisture content were determined by drying sub samples at 70°C, for calculation of dry grain and straw yields. The number of grains per spike was determined on 20 spikes randomly selected from each plot. Average grain weight (dry) was determined with 1000 grains randomly sampled from the large area harvest. Water productivity was calculated as:

$$\text{Irrigation Water productivity, IWP (kg/m}^3\text{)} = \frac{\text{Gain yield (kg/ha)}}{\text{Volume of irrigation water (m}^3\text{)}}$$

RESULTS AND DISCUSSION

Soil water dynamics: The moisture content at field capacity was slightly higher (0.303 cm^3/cm^3) at 30–50 cm soil layer in comparison to the other two soil layers. Similar trend was also observed in available water content. Soil moisture content was highest at 30–50 cm soil layer (0.248 cm^3/cm^3) followed by 15–30 cm (0.239 cm^3/cm^3) and 0–15 cm (0.234 cm^3/cm^3) soil layer, respectively. The higher amount of volumetric moisture content at lower depth can be attributed to a higher amount of clay content resulting in a greater number of micro-pores. The higher clay content at lower depth is due to leaching of finer soil particles from upper layers.

Growth attributes: Variation in soil moisture potential and depth of tensiometer did not affect the establishment of plants (Table 1). Hence the number of plants per meter was same at different levels of tensiometer pressure and depth at 15 and 30 DAS. Tillers per meter row length increased with crop age and attained its peak at 60 DAS and after that gradually decreased. The number of tillers per meter row length did not differ significantly due to variation in pressure and depth of tensiometer at 30 DAS, but afterwards, they differed significantly. Irrigation threshold at 20 kPa produced a significantly higher number of tillers per meter than 50 kPa, but it was similar to 35 kPa. The maximum number of tillers per meter was produced when irrigation was given at 35 cm tensiometer depth which was significantly superior over 50 cm depth, but similar to 20 cm depth. Plant height at 20 and 35 kPa was same but significantly taller than that at 50 kPa. Likewise, similar plant height was attained at 20 and 35 cm depth of tensiometer but significantly lower at 50 cm depth.

Yield and yield attributes: The effective tiller count was taken from 1 m row length and irrigation scheduling had shown marked effects on effective tillers. The maximum number of effective tillers per unit area was at a tensiometer pressure of 20 kPa, which was significantly superior over 50 kPa but similar to those of 35 kPa (Table 1). A significant increase in grain yield with increasing irrigation frequency under normal soil conditions was reported by Ram *et al.* (2013). Other yield components, viz. spike length, grains/spike and test weight showed a similar trend. Grain and straw yield was also influenced by tensiometer pressure. Highest grain and straw yield (3.57 and 4.35 t/ha) was obtained at 20 kPa which was similar to that of 35 kPa but significantly higher over 50 kPa. Installation of tensiometer at different soil depths influenced the amount of irrigation

Table 1 Effect of tensiometer depth and soil moisture potential on number of plants, tillers, yield and yield attributes (Pooled data of three years)

Treatment	No. of plants/m		Tillers/m row length				Plant height at harvest (cm)	Effective tillers/m	Effective tillers/m²	Spike length (cm)	Grains/ spike	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
	15 DAS	30 DAS	30 DAS	60 DAS	90 DAS	Maturity								
Pressure														
p_1 (20 kPa)	30.2	40.8	15.3	85.3	80.5	77.1	92.6	64.0	320	9.26	40.0	38.1	3.57	4.35
p_2 (35 kPa)	31.7	41.1	14.6	83.2	78.3	75.0	90.5	62.0	310	9.13	39.0	37.2	3.46	4.29
p_3 (50 kPa)	30.1	39.6	13.8	74.6	71.2	67.6	87.1	56.0	280	8.71	34.3	35.9	2.86	3.58
CD (P=0.05)	NS	NS	NS	6.62	5.79	5.58	2.52	4.8	19.8	0.36	1.50	1.11	0.23	0.30
Tensiometer depth														
d_1 (20 cm)	31.0	40.4	14.4	81.1	76.1	73.3	90.2	61.0	305.0	9.12	37.5	37.2	3.36	4.15
d_2 (35 cm)	30.4	41.3	15.7	85.6	80.7	76.2	91.5	63.0	315.0	9.20	38.7	37.6	3.39	4.20
d_3 (50 cm)	29.6	39.8	13.6	76.4	73.2	70.2	88.5	58.0	290.0	8.78	37.1	36.4	3.14	3.87
CD (P=0.05)	NS	NS	NS	6.62	5.79	5.58	2.52	4.8	19.8	0.36	1.5	1.11	0.23	0.30

*Net plot area=11 × 4.5 m^2

water, hence affecting the yield and yield components. At 35 cm soil depth maximum number of effective tillers per unit area, spike length, grains/spike and test weight were recorded which were at par with 20 cm soil depth and significantly more than 50 cm soil depth. Grain and straw yield also showed the same trend.

Irrigation water productivity: The highest yield (4.1 t/ha) was obtained with the treatment p_2d_1 i.e. when irrigation was governed at 35 kPa at 20 cm depth. It was at par with p_1d_2 and p_1d_3 i.e. when irrigation was applied at a pressure of 20 kPa and a depth of 35 and 50 cm producing 4.0 and 3.90 t/ha grain yield, respectively. The lowest yield was obtained at a pressure of 50 kPa at a depth of 50 cm. This irrigation water also includes rainfall over the period (Table 2). Maximum irrigation water was applied in plots where the tensiometer was set at 20 kPa. However, as the depth of tensiometer increased beyond 20 cm, required amount of irrigation water decreased (Table 2). This may be due to presence of more moisture in lower strata of soil (35–50 cm) as compared to above layer. It may be inferred that crop receiving 22.5 and 26.67 cm water, produced significantly higher grain yield (4.10, 4.0 and 3.98 t/ha) over other irrigation treatments (Table 2). The crop receiving excess amount of irrigation water had a damaging effect on wheat yield (Torrion and Stougaard 2017) and reduced yield approximately by more than 1 t/ha, i.e. the treatment p_1d_1 where 35.6 cm irrigation water was applied, produced lower yield (2.82 t/ha). Similarly, in case of deficit irrigation (less than 22.5 cm) also, the yield showed a decreasing trend.

Generally, water productivity decreases with an increase in irrigation volume. Deficit irrigation effectively boosted irrigation water productivity with an increase in depth and pressure of tensiometer. Highest irrigation water productivity i.e. 1.809 kg/m^3 was achieved under deficit irrigation (8.87 cm) with least grain yield (2.6 t/ha). Highest grain yield (4.1 t/ha) was obtained at 35 kPa at 20 cm depth with water productivity of 1.464 kg/m^3. Thus, it may be concluded that an excess amount of applied water or deficit irrigation does not guarantee better water productivity (Nand *et al.* 2011). The main concern for a farmer is the crop yield. Hence, there should be an optimum level of soil moisture potential at which the irrigation should be given. The depth of tensiometer and providing irrigation based on soil moisture potential affect wheat yield as well as water productivity. Irrigation scheduling based at a soil moisture potential of 35 kPa at 20 cm or 20 kPa at 50 cm depth of tensiometer resulted in a significantly higher yield of wheat. Amount of irrigation water at a pressure of 35 kPa at 20 cm or 20 kPa at 50 cm depth of tensiometer was approximately equal (22.5 cm) and crop receiving 22.5 cm water, produced significantly higher grain yield (4.03 and 3.98 t/ha) over other irrigation treatments. An optimum level of wheat yield and water productivity should be chosen based on soil moisture potential and tensiometer depth. For a farmer, the tensiometer depth of 20 cm is recommended as it can be easily adopted by them.

Table 2 Interaction effect of soil moisture potential and tensiometer depth on Yield, applied irrigation water and irrigation water productivity

Soil moisture potential	Depth of Tensiometer (d)			
	d_1 (20 cm)	d_2 (35 cm)	d_3 (50 cm)	Mean
Yield (t/ha)				
p_1 (20 kPa)	2.82	4.03	3.80	3.57
p_2 (35 kPa)	4.10	3.35	2.92	3.46
p_3 (50 kPa)	3.15	2.82	2.60	2.86
Mean	3.36	3.39	3.14	
CD (P=0.05) for D: 0.23, CD (P=0.05) for P: 0.23, CD (P=0.05) for P×D: 0.40				
Applied irrigation water (cm)				
p_1 (20 kPa)	35.60	26.67	22.50	28.26
p_2 (35kPa)	22.50	15.00	11.67	16.39
p_3 (50kPa)	12.50	10.83	8.87	10.73
Mean	23.53	17.50	14.35	
CD (P=0.05) for D: 2.20, CD (P=0.05) for P: 2.20, CD (P=0.05) for P×D: 3.82				
Irrigation Water Productivity (kg/m^3)				
p_1 (20 kPa)	0.686	1.243	1.393	1.107
p_2 (35kPa)	1.464	1.634	1.701	1.600
p_3 (50kPa)	1.750	1.727	1.809	1.762
Mean	1.300	1.535	1.634	
CD (P=0.05) for D: 0.24, CD (P=0.05) for P: 0.24, CD (P=0.05) for P×D: 0.41				

(Pooled data of 3 years)

ACKNOWLEDGEMENTS

Authors are grateful to International Rice Research Institute, Philippines and Indian Council of Agricultural Research, New Delhi for providing financial assistance and manpower for conducting the research work.

REFERENCES

Bhatt R, Kukal S S, Busari M A, Arora S and Yadav M. 2016a. Sustainability issues on rice-wheat cropping system. *International Soil and Water Conservation Research* **4**: 68–83.

Bhatt R, Arora S and Chew C C. 2016b. Improving irrigation water productivity using Tensiometers. *Journal of Soil and Water Conservation* **15**(2): 120–4.

Brauman K A, Siebert S and Foley J A. 2013. Improvements in crop water productivity increase water sustainability and food security—a global analysis**.** *Environmental Research Letters* **8**: 24–30

Kukal S S, Singh Y, Jat M L and Sidhu H S. 2014. Improving water productivity of wheat-based cropping systems in South Asia for sustained productivity. *Advances in Agronomy* **127**:159–230.

Michael C C. 2012. Using tensiometers for scheduling irrigations of coastal vegetables. University of California U.S. Cooperative Extension. http://cemonterey.ucanr.edu/files/171009.pdf

Nand B, Khokhar R P S and Pyare R. 2011. Studies on irrigation scheduling of wheat varieties for central Uttar Pradesh, India. *Plant Archives* **11**: 243–8.

Ram H, Dadhwal V, Vashist K K and Kaur H. 2013. Grain yield and water use efficiency of wheat (*Triticum aestivum* L.) in relation to irrigation levels and rice straw mulching in North West India. *Agricultural Water Management* **128**: 92–101.

Sevostianova E, Deb S, Serena M, VanLeeuwen D and Leinauer B. 2015. Accuracy of two electromagnetic soil water content sensors in saline soils. *Soil Science Society of America Journal* **79**: 1752–9.

Singh B, Humphreys E, Eberbacha PL, Katupitiyac A, Singh Y and Kukal S S. 2011. Growth, yield and water productivity of zero till wheat as affected by rice straw mulch and irrigation schedule. *Field Crops Research* **121**(2): 209–25.

Torrion J A and Stougaard R N. 2017. Impacts and Limits of Irrigation Water Management on Wheat Yield and Quality. *Crop Science* **57**: 3239–51.

Yadav S, Singh B, Humphreys E and Kukal S S. 2013. Effective management of scarce water resources in North-West India. *Agricultural Sustainability: Effective Management of Scarce Water Resources in North-West India*, 1st edn, pp. 103-126. Bhullar G S and Bhullar N K (Eds). Academic Press, Elsevier, London, UK.

Vashisht B B. 2019. Management interventions to enhance productivity of wheat and water use in changing climate of Indian Punjab. (*In) Proceedings of 23rd Cambridge International Manufacturing Symposium University of Cambridge*, 26–27 September 2019. pp 1–6.