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Research Paper

# Water use and productivity of drip irrigated wheat under variable climatic and soil moisture regimes in North-West, India

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ABSTRACT

In North-Western India, wheat is normally irrigated at an IW: CPE of 0.9, with 75 mm depth of irrigation water (conventional irrigation practice, CP) resulting in wastage of water. An effective irrigation strategy is required that will save irrigation water without compromising yield penalty. So, an experiment was conducted at Punjab Agricultural University, Ludhiana during 2014–15 and 2015–16 in split plot design, keeping four sowing dates {25th October ($D_1$), 10th November ($D_2$), 25th November ($D_3$) and 10th December ($D_4$)} in the main plots and five irrigation schedules {irrigation at 15 ($FC_{15}$), 25 ($FC_{25}$), 35 ($FC_{35}$) and 45 ($FC_{45}$)% depletion of soil moisture from field capacity (FC) and a conventional practice} in sub plots. The objectives of the study were to evaluate the effect of drip irrigation amounts on field water balance, yield and water productivity of wheat. The results revealed that mean grain yield decreased by 8.3 & 8.7, 10.7 & 10.6 and 13.1 & 13.4% from $D_1$ to $D_2$, $D_2$ to $D_3$ and $D_3$ to $D_4$ during 2014-15 and 2015-16, respectively. Pooled grain yield decreased by 29% with delay in sowing from $D_1$ to $D_4$. Reduction in ETc was 10% in $D_4$ as compared to $D_1$ during 2014-15 and 24% during 2015-16. The highest grain yield was obtained with irrigation applied at 15% depletion from FC. The pooled grain yield decreased by 30%, ETc by 21% and water productivity by 29% in $FC_{45}$ as compared to $FC_{15}$. The water saving in drip irrigation during 2014-15 was 62, 70, 77 and 83% in $FC_{15}$, $FC_{25}$, $FC_{35}$ and $FC_{45}$ respectively as compared to CP. The respective values during 2015-16 were 38, 44, 54 and 60%. The results demonstrate that irrigating wheat at 15% depletion of FC using drip method of irrigation as a novel concept that saves irrigation water in addition to higher grain yield.

## 1. Introduction

Punjab, known as the bread basket of India, has 3.51 million ha under wheat cultivation with production and productivity of 17 million tonnes and 4.85 t $ha^{-1}$, respectively. The state alone contributes 40% of wheat to the central pool, critical for the food security of India (GOI, 2014). The crop is sensitive to variations in environmental conditions for better emergence, growth and flowering (Dabre et al., 1993) and is more vulnerable to high temperature exposures during reproductive stages (Kalra et al., 2008; Farooq et al., 2011). The choice of sowing date is an important management practice to optimize the grain yield of wheat. Numerous studies (Bassu et al., 2009; Bannayan et al., 2013) have reported yield advantage with early sowing and yield reduction under delayed sowing after the optimum time (Qasim et al., 2008; Yajam and Madani, 2013). Date of sowing influences the water use and water productivity through effect on crop evapotranspiration and ultimately on grain yield. The yield and consumptive use vis-à-vis water productivity decreases with delay in sowing beyond normal sowing window (Gao et al., 2014).

In wheat season, average total and long term average (45 years) rainfall were 115 mm and 12–252 mm, respectively under Punjab conditions. The rainfall is poorly distributed relative to the crop need resulting in heavy dependence on irrigation for optimal yield realization. For this reason, the farmers pump groundwater to irrigate wheat to alleviate the evapotranspiration (ET) deficit. The indiscriminate pumping of groundwater has led to fast depletion of aquifers in 80% area of Punjab at an alarming rate of 0.4 m $year^{-1}$ (Brar et al., 2012). Therefore, it is need of the hour to check the falling rate of groundwater table by reducing the amount of irrigation in keeping with high grain yield. This implies the need for refining irrigation scheduling from plentiful to limited irrigation vis-a-vis evaluating novel precise irrigation methods. Effective irrigation management strategies aid in improving crop water productivity (WP) through regulated timing and application of irrigation water; having the potential to deliver only the required amount of water for crop use. For similar reasons, interest in drip irrigation is increasing in the water scarcity regions of the world.

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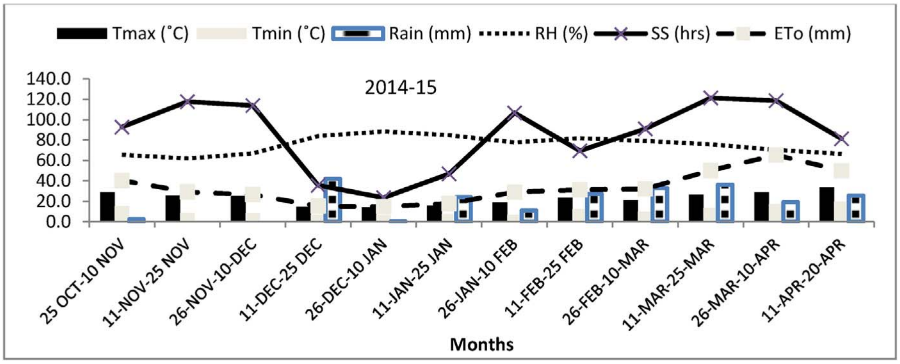


**Fig. 1.** Fortnightly mean max temperature, min temperature and relative humidity and cumulative fortnightly sunshine hours, potential evapotranspiration and rainfall during 2014-15.

Drip irrigation is defined as the precise, slow application of water in the form of discrete or continuous or tiny or miniature spray through mechanical devices called emitters located at selected points along water delivery lines.

Knowledge of the influence of irrigation management on water balance, crop water use and requirements are the practical considerations to improve yield, crop water productivity (Brar et al., 2012) and irrigation water productivity (Brar et al., 2017). Several studies in Punjab have investigated the irrigation water requirements based on ET (Timsina et al., 2008), irrigation water/pan evaporation (Prihar et al., 1976), but very less are based on soil water deficit (SWD) (Prihar et al., 1978; Timsina et al., 2008). Prihar et al. (1978) observed no yield decline when crop was irrigated after depletion of 50–110 mm available soil water from the 180 cm profile. But grain yield declined largely when irrigated at a depletion of 140–170 mm. Panda et al. (2003) reported similar grain yield at a depletion of 15–45% of available soil water (ASW) and reduced yields for 60–75% depletion of ASW. However, all of these studies were under flood irrigated conditions and no literature is available for drip irrigation conditions. Marked differences in crop water use and water productivity due to varying rainfall, evaporative demand and irrigation timing has been reported by several authors under flood irrigated conditions (Kang et al., 2002; Bandyopadhyay and Mallick, 2003; Panda et al., 2003; Irmak et al., 2016). Most of the researchers have reported an increase in crop evapotranspiration with increase in irrigation levels, with values ranging from 227 mm (Dutta and Das, 2001), 250 mm (Bandyopadhyay and Mallick., 2003), 290 mm (Majumdar and Mandal, 1984), to 337 mm (Tyagi et al., 2000). However, the results were contrasting with regard to water productivity. An increase in crop water productivity (CWP) with increase in irrigation amount and ET was reported by Bandyopadhyay and Mallick, (2003), Kang et al., (2002), El-Hendawy and Schmidhalter (2010), Irmak et al., (2016) and a decrease in CWP with higher irrigation and ET amounts was reported by Panda et al., (2003) and Sun et al., (2006). The trade-offs between irrigation, crop ET and yield were also reported in different perspectives by different researchers; El-Hendawy and Schmidhalter, (2010) reported linear and positive relationship for yield versus ET for all irrigation frequency and water application rate combinations. But Sun et al. (2006) addressed quadratic relation between irrigation supply and grain yield. For most crops, grain yield is a linear function of seasonal crop ET (Vaux and Pruitt, 1983).

No work has been reported in Punjab regarding the water requirement, water balance and yield of wheat based on soil water deficit schedule under drip irrigation conditions. So, this study was conducted with the following objectives: (1) to study the field water balance of drip irrigated wheat, (2) to understand the trade-offs between irrigation, evapotranspiration, yield and water productivity of drip irrigated wheat grown in Punjab, North-western India.

## 2. Materials and methods

### 2.1. Site description

A field experiment was conducted during two wheat growing seasons (2014–15 and 2015–16) at the research farms of Punjab Agricultural University (PAU), Ludhiana, India (30° 54′ N, 75° 48′ E, elevation 247 m above sea level). The climate of the area is semi-arid, with average annual rainfall of 700 mm (75–80% of which is received in July-September) and average wheat season rainfall of 115 mm, daily minimum temperature of 0–4 °C in January and daily maximum temperature of 40–45 °C in May. The weather data was obtained from meteorological observatory, PAU, located 200 m from the experimental site. Seasonal weather data during 2014–15 and 2015–16 wheat growing season including mean maximum temperature, minimum temperature and relative humidity; cumulative fortnightly rainfall, sunshine hours and reference evapotranspiration is presented in Figs. 1 and 2.

The mean maximum and minimum temperature during 2014-15 growing season were 22.3 °C and 10.4 °C for 25 Oct sowing ($D_1$); 21.7 °C and 10 °C for 10 Nov sowing ($D_2$); 21.5 °C and 10.3 °C for 25 Nov sowing ($D_3$); and 21.5 °C and 10.9 °C for 10 Dec sowing ($D_4$) respectively (Table 1 and Fig. 1). The mean RH varied from 76 to 79% during 2014–15 and 66.8-68.2% during 2015-16. During 2015-16, the mean maximum and minimum temperature were 24 °C and 10.9 °C for $D_1$; 23.9 °C and 10.7 °C for $D_2$; 24.1 °C and 10.9 °C for $D_3$; and 24.3 °C and 11.1 °C for $D_4$ respectively (Table 1 and Fig. 2). The total sunshine

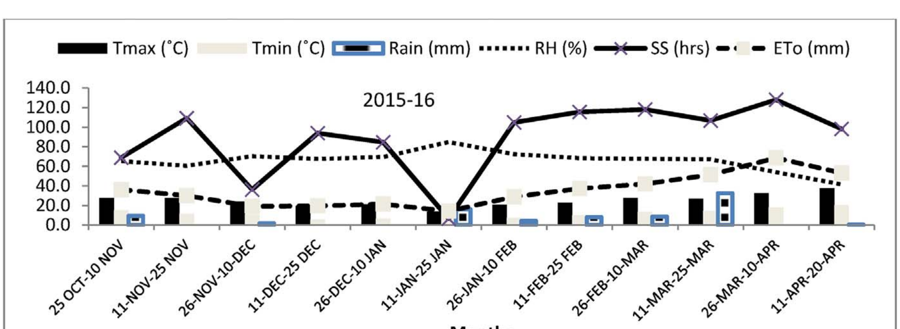


**Fig. 2.** Fortnightly mean max temperature, min temperature and relative humidity and cumulative fortnightly sunshine hours, potential evapotranspiration and rainfall during 2015-16.