



Water dynamics, productivity and heat use efficiency responses in wheat (*Triticum aestivum*) to land configuration techniques and irrigation schedules

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ABSTRACT

The present study was conducted during 2012–13 and 2013–14 to investigate the effect of different land configurations and irrigation schedules on soil water depletion, ground water contribution (GWC), productivity and heat use efficiency of wheat (*Triticum aestivum* L. emend. Flori & Paol). Results of the two years study exhibited highest grain yield by 24.7% and 17.4%, water use efficiency (WUE) by 38.8% and 35.7%, respectively, under furrow irrigated raised beds (FIRBS) over conventional tillage (CT). Soil moisture depletion, GWC and total consumptive water use were lowered by 21% and 15%, 20% and 16%, and 12% and 9%, respectively over CT in both the years. Under zero tillage (ZT) condition, wheat accumulated highest growing degree days (GDD) of 3288°C day and 3321°C day, respectively. Furthermore, FIRBS and ZT plots accumulated additional heat units of 1000°C day-hour till maturity in both the years. Among the irrigation schedules, contribution of irrigation water towards consumptive water use was highest by 41.8% and 43.6% in IW:CPE=0.90 over others in 2 years, respectively. Irrigation water productivity (WP_i) was highest by 45.8% and 43.3% in IW:CPE=0.75, respectively.

Key words: FIRBS, GWC, Heat units, HUE, Productivity, Water use

Water shortage and injudicious use, is the primary factor limiting individual factor productivity and economic development in semi-arid conditions. Wheat (*Triticum aestivum* L.) is irrigated by surface irrigation methods where the irrigation efficiency to be as low as 30–40% as compared to attainable level of 60–70% (Idnani and Kumar 2013) because of higher non-beneficial evapotranspiration. In most of the western Haryana region of India, shallow water table particularly in winter season influences the productivity of wheat ecosystem. Shallow water table exerts a strong influence on crop productivity enhancement during deficit periods (Nosetto *et al.* 2009), or can hamper crop performance due to salt transport into the root zone (Florio *et al.* 2014). Conventional flood irrigation with excess amount of irrigation water influences on fluctuating water table and its subsequent effect on winter crops.

Climatic factors, viz. temperature, rainfall and light which in favourable range are most important for exploiting potentiality of crop. Temperature and light primarily affect duration of crops through interception of solar radiation by the crop. Temperature indices, viz. growing degree days (GDD) and heat use efficiency (HUE) have been widely used to describe changes in phenological behaviour and

growth parameters (Streck *et al.* 2008) depending on crop type, genetic factors and sowing time (Majumder *et al.* 2016). Whereas, exposure to heat stress accelerates the development stages in wheat crop which in turn leads to reduced grain yield as well as quality (Kajla *et al.* 2015). The impact of high temperature on wheat productivity can be minimized, if one can have knowledge on GDD and heat units by adoption of various agronomic management practices. However, modification of soil microclimate in terms of land configuration and irrigation practices also plays a greater role in accumulating GDD and heat units in wheat. However, the recital of water distribution and its obtainability in the soil root zone to the crop is diverged under field conditions with improved techniques. In this paper we characterized the dynamics of water use and radiation use efficiency under various land configuration techniques and its effect on the performance of wheat.

MATERIALS AND METHODS

The study was conducted in CCS Haryana Agricultural University, Hisar during winter seasons of 2012–13 and 2013–14. Mean rainfall received during winter 2012–13 (113.8 mm) and 2013–14 (78.6 mm) was well distributed over the entire crop period. The mean pan evaporation was 357.2 and 341.1 mm, respectively. Temperature conditions were normal during the respective crop seasons. The experimental soils had 1.42 g/cc bulk density, contained 0.58% organic carbon and 4.6 mm/h infiltration rate. The

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water table depth in the experimental field was 148 and 152 cm; fluctuated around 141 and 155 cm during the active growth period of the crop during 2012–13 and 2013–14, respectively.

We evaluated the yield response of wheat during 2012–13 and 2013–14 with cultivar WH 711. The exploration consisted combinations of land configuration techniques defined as; conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and furrow irrigated raised bed system (FIRBS) in main plots with irrigation schedules defined as; CRI+IW:CPE=0.90 (I_1), CRI+IW:CPE=0.75 (I_2) and CRI+IW:CPE=0.60 (I_3) in subplots. The study was replicated thrice using strip plot design. The standard tillage practices were followed for establishing the wheat in respective methods and sowing was done using seed drill. ZT was subjected to no tillage system and the experiment was carried out on the same layout during both the years. The plots were maintained free of weeds throughout the whole cycle with herbicides, particularly glyphosate (in ZT plots) and pendimethalin (in FIRBS, CT and MT). These plots were sown on 4th and 5th December during the respective crop seasons.

A fixed depth of 50 mm irrigation water was applied and these were then computed to have their cumulative values. These values were used to calculate the desired ratios of IW:CPE. Irrigations were applied in individual plots based on the IW:CPE and the depth was measured with the help of *current meter*. One common irrigation was given at crown root initiation stage (25 days after sowing) and thereafter treatments were imposed based on IW:CPE. The total number of post-sown irrigations applied were 3, 2 and 2 during both the years under IW:CPE = 0.90, 0.75 and 0.60 moisture regimes, respectively. The soil water flux density from water table depth to root zone was estimated using Darcy's law for steady state conditions as proposed by Giesel *et al.* (1972). The depletion from soil, rainfall, contribution from shallow ground water, and post-sown irrigations were used to estimate consumptive use of water. Soil profile moisture depletion was calculated by using gravimetric method as proposed by Rajanna *et al.* (2016).

The total water use, water use efficiency, and irrigation water productivity were calculated as per the standard procedures.

The sequential phasic development of the wheat crop (crop phenology) was recorded in terms of number of days taken to spike emergence, anthesis, milking and maturity of the plants as reported by Rajanna *et al.* (2017). Wheat took an average of 45, 91, 106 and 131 days under ZT; CT – 46, 89, 103 and 126 days; MT– 46, 90, 103 and 129 days; and FIRBS– 44, 90, 106, 132 days in 2 crop seasons. Different parameters that defined intercepted radiations, such as accumulated growing degree days (GDD), helio–thermal units (HTU) and heat use efficiency (HUE) in the cycle were computed with average values. The period considered for the analysis was from December to end of April. GDD was calculated with a base temperature of 5°C by using standard formulae.

$$GDD = \frac{T_{\max} + T_{\min}}{2} - T_{\text{base}} \quad (1)$$

where, $T_{\max}$ = Daily maximum temperature (°C); $T_{\min}$ = Daily minimum temperature (°C); T_{base} = Base temperature of 5°C

HTU, the product of GDD and corresponding actual sunshine hours for that day were computed on daily basis as:

$$HTU = GDD \times \text{Actual Sunshine hours} \quad (2)$$

Growing degree–days and heliothermal units were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to give accumulated indices. The HUE is the amount of above ground dry matter produced per degree day. It was calculated by using the following formula:

$$HUE \text{ (g/m}^2\text{/}^\circ\text{C day)} = \frac{\text{Grain yield (g/m}^2\text{)}}{AGDD \text{ (}^\circ\text{C day)}} \quad (3)$$

Wheat harvested manually 1 week after physiological maturity in 2012–13 and 2013 – 14. For each plot, yield was determined from net plot area of 8.4×4.5 m (37.8 m²). Threshing done after sun-drying for 48 h and final grain yield was determined. The data were analysed during both

Table 1 Effect of land configuration techniques and irrigation schedules on accumulated growing degree days (°C day) at different growth stages of wheat during 2012–13 and 2013–14

Treatment	2012–13					2013–14				
	Spike initiation	Anthesis	Milk stage	Maturity	Total	Spike initiation	Anthesis	Milk stage	Maturity	Total
<i>Land configuration technique</i>										
FIRBS	266d	692ab	924ab	1389a	3270ab	292c	719ab	940ab	1355a	3307ab
CT	289ab	672d	887c	1281d	3129d	290d	693d	905c	1291d	3178d
MT	292a	689abc	887c	1340c	3208c	300b	708c	903d	1323bc	3235c
ZT	280bc	701a	935a	1372ab	3288a	306a	726a	948a	1341ab	3321a
<i>Irrigation schedule, irrigation at IW:CPE</i>										
0.90	281a	694a	921a	1360a	3256a	297a	722a	928a	1338a	3286a
0.75	282a	691ab	910ab	1349b	3233ab	297a	711b	926ab	1332ab	3266ab
0.60	283a	680c	893c	1328c	3183c	297a	702c	918c	1312c	3229c

Table 2 Accumulation of heliothermal units (°C day hours) at different growth stages of wheat under land configuration techniques and irrigation schedules during 2012–13 and 2013–14

Treatment	2012–13					2013–14				
	Spike initiation	Anthesis	Milk stage	Maturity	Total	Spike initiation	Anthesis	Milk stage	Maturity	Total
<i>Land configuration technique</i>										
FIRBS	1674a	4327ab	6333ab	10231a	22566ab	1664a	3953ab	5752ab	9276a	20644a
CT	1707a	4124c	5993c	9262d	21085d	1673a	3760d	5445c	8659d	19537d
MT	1718a	4298ab	5989cd	9801c	21806c	1673a	3876c	5430d	8992bc	19971c
ZT	1707a	4415a	6435a	10083ab	22639a	1687a	3998a	5810a	9145ab	20640ab
<i>Irrigation schedule, irrigation at IW:CPE</i>										
0.90	1707a	4350a	6307a	9974a	22337a	1673a	3961a	5643a	9117a	20395a
0.75	1706a	4316ab	6209ab	9884ab	22115ab	1676a	3896ab	5624ab	9060ab	20257ab
0.60	1692a	4207c	6047c	9674c	21620c	1674a	3833c	5559c	8876c	19942c

the crop seasons using analysis of variance (ANOVA) technique for a strip plot design. The analysis of variance was performed using SAS package. The data from each attributes were analysed separately and the means among treatments were compared based on the least significant difference (LSD) test at 5% level of significance ($P = 0.05$).

RESULTS AND DISCUSSION

Grain yield and weather: Growth, water use and consequently the yield potential of wheat was greatly influenced by the weather conditions prevailing during the crop season. The sum of rainfall of 11.38 and 7.86 cm, and the pan evaporation of 357.2 and 341.1 mm was recorded during winter 2012–13 and 2013–14, respectively. Maximum rainfall of 6.22 cm received from crown root initiation (CRI) to 74 days after sowing (DAS) period, while other growth periods received very little amount of rainfall. During 2013–14, no rainfall received at CRI to 81 DAS. The temperatures were in the normal range and congenial for growth and development of wheat during respective crop seasons.

Land configuration techniques and irrigation schedules had highly significant effect on grain yield of wheat in both

years ($P < 0.05$, Table 3). Significantly higher grain yield of wheat was obtained with FIRBS over CT and MT in both the years but no significant difference was observed between FIRBS and ZT. Wheat yield under FIRBS would depend on how vigorously the plants capture solar radiation falling in the gap between outer rows. It could also attribute to longer grain filling duration in FIRBS (Rajanna *et al.* 2017). Compared to CT, the grain yield obtained under FIRBS and ZT treatments increased by 24.7% and 17.4% in 2012–13 over MT, and by 23.6 and 20.0% in 2013–14, respectively over CT. Grain yield increased with successive increase in irrigation level in both the years. Likewise, grain yield of wheat increased by 10.4% and 4.5% with IW:CPE= 0.90 over IW:CPE=0.60 during both the years. Higher grain and biological yields of wheat were observed with higher moisture regimes due to collective effect of dry matter production and yield attributes (Patil *et al.* 2014).

Soil moisture depletion (SMD): The SMD under the land configuration techniques and irrigation schedules increased with cumulative duration of crop growth stages in 2012–13 and 2013–14. Lowest SMD observed up to 74 DAS and increased with advancement of the crop. From CRI to 74 DAS, almost equal amount of soil moisture depleted

Table 3. Grain yield, water productivity, water use efficiency and heat use efficiency of wheat under various land configurations and irrigation schedules during 2012–13 and 2013–14

Treatment	Grain yield (kg/ha)		Irrigation water productivity (kg/m ³)		Water use efficiency (kg/ha-mm)		Heat use efficiency (g/m ² /°C)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
<i>Land configuration technique</i>								
FIRBS	5165a	5508a	4.29a	4.45a	14.5a	15.5a	0.360ab	0.369a
CT	4831b	4457d	3.46b	3.22c	11.9c	11.5c	0.364a	0.327d
MT	4142c	4833c	3.00c	3.52c	10.4d	12.7c	0.319d	0.353bc
ZT	4861b	5347ab	3.63b	4.00ab	12.6b	14.4ab	0.338c	0.363ab
<i>Irrigation schedule, irrigation at IW:CPE</i>								
0.90	4945a	5299a	2.90c	3.09c	12.1b	13.5b	0.352a	0.364a
0.75	4825ab	5070b	4.22a	4.43a	12.9a	14.0a	0.349ab	0.352b
0.60	4480c	4741c	3.93ab	4.16ab	11.9bc	13.0c	0.335c	0.342c

from all the treatments in 2 years. However, highest soil moisture depletion observed in CT from 75 to 122 DAS 3 growth phases over FIRBS and slightly lower moisture was depleted from MT and ZT compared to CT at all the 3 growth stages. Depletion of soil moisture at 0–90 cm by wheat under FIRBS was least over other techniques in 2 years (Fig 1) probably due to nature of land configuration, wherein least quantity of water is applied through furrows, crop utilized lateral movement of water for growth and development. The total depletion was relatively higher under CT followed by MT and ZT, and least in FIRBS. Compared to CT, the depletion was lower by 21%, 11% and 5% in 2012–13, and 15%, 12% and 6% in 2013–14 under FIRBS, ZT and MT, respectively. Likely, soil moisture content is generally higher under ZT than under CT throughout the crop growth period. In ZT wheat, the SMD was lower than CT due to higher soil moisture conservation (Carefoot *et al.* 1990). Among the irrigation schedules, maximum SMD observed in IW:CPE=0.90 followed by IW:CPE=0.75 over

IW:CPE=0.60 at all the growth periods. The total depletion in 2012–13 was relatively highest by 12% in I_1 (6.81 cm) over other 2 moisture regimes. In 2013–14, highest depletion recorded with I_3 (8.02 cm), and least under I_1 by 17% (Fig. 1). The aggregate of 15–16% and 18–20% soil moisture contributed through SMD in respective 2 years towards total consumptive use, it was least compared to rainfall, irrigation water and GWC.

Ground water contribution (GWC): The GWC towards crop water use up to CRI stage was low and increased with advancement of the crop during both the crop seasons. From CRI to 74 DAS, almost equal amount of GWC was observed in various land configuration techniques and irrigation schedules. Maximum GWC was found under CT during various growth periods as compared to FIRBS (Fig 2). Contrastingly, in 2013–14 maximum GWC recorded at 95 to 106 DAS and 107 to 117 DAS periods over other growth stages. The cumulative GWC by the wheat crop towards water flux was least by 20%, 11% and 6% in 2012–13, and

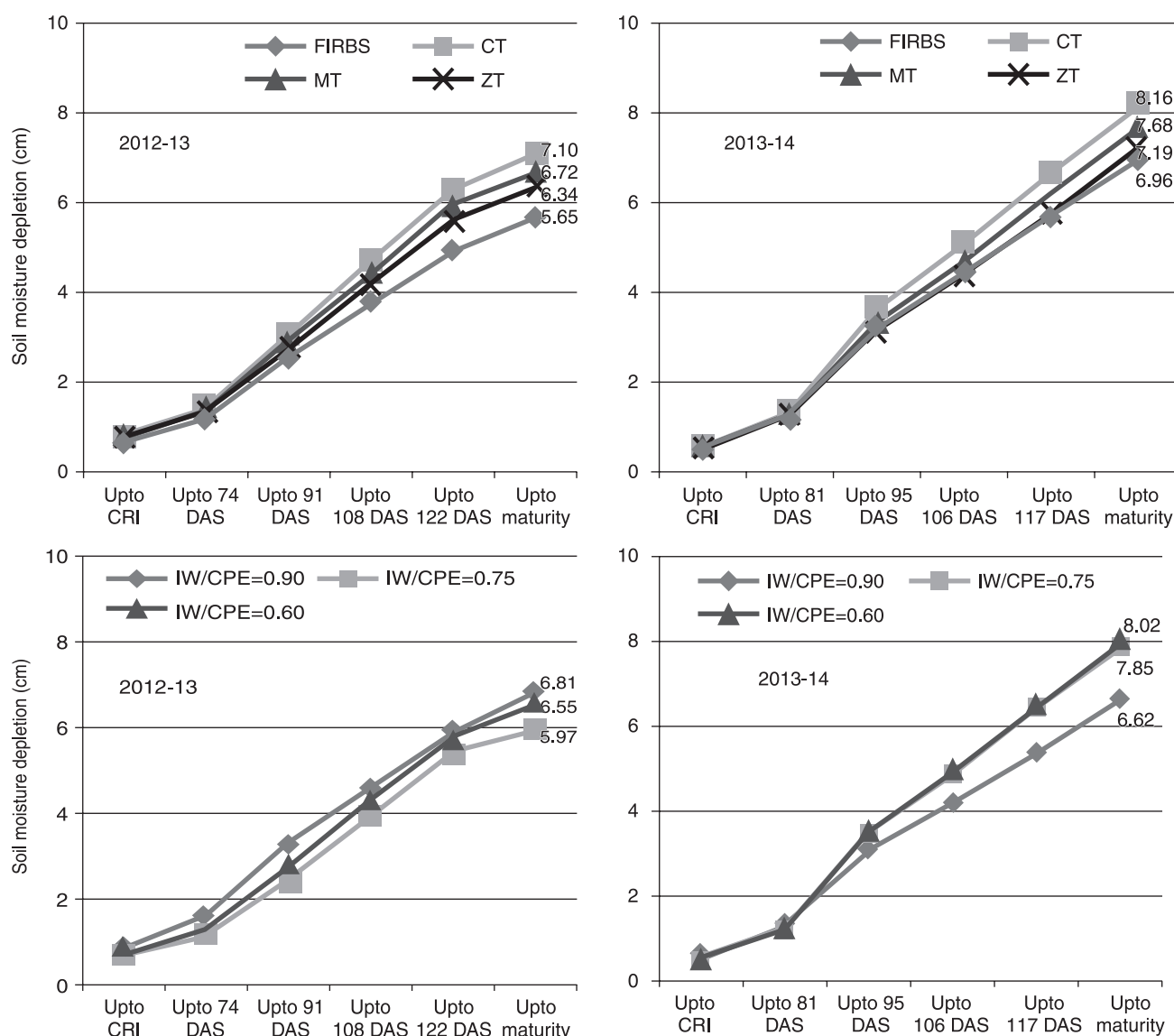


Fig 1 Cumulative soil moisture depletion (cm) during wheat in 2012–13 and 2013–14.

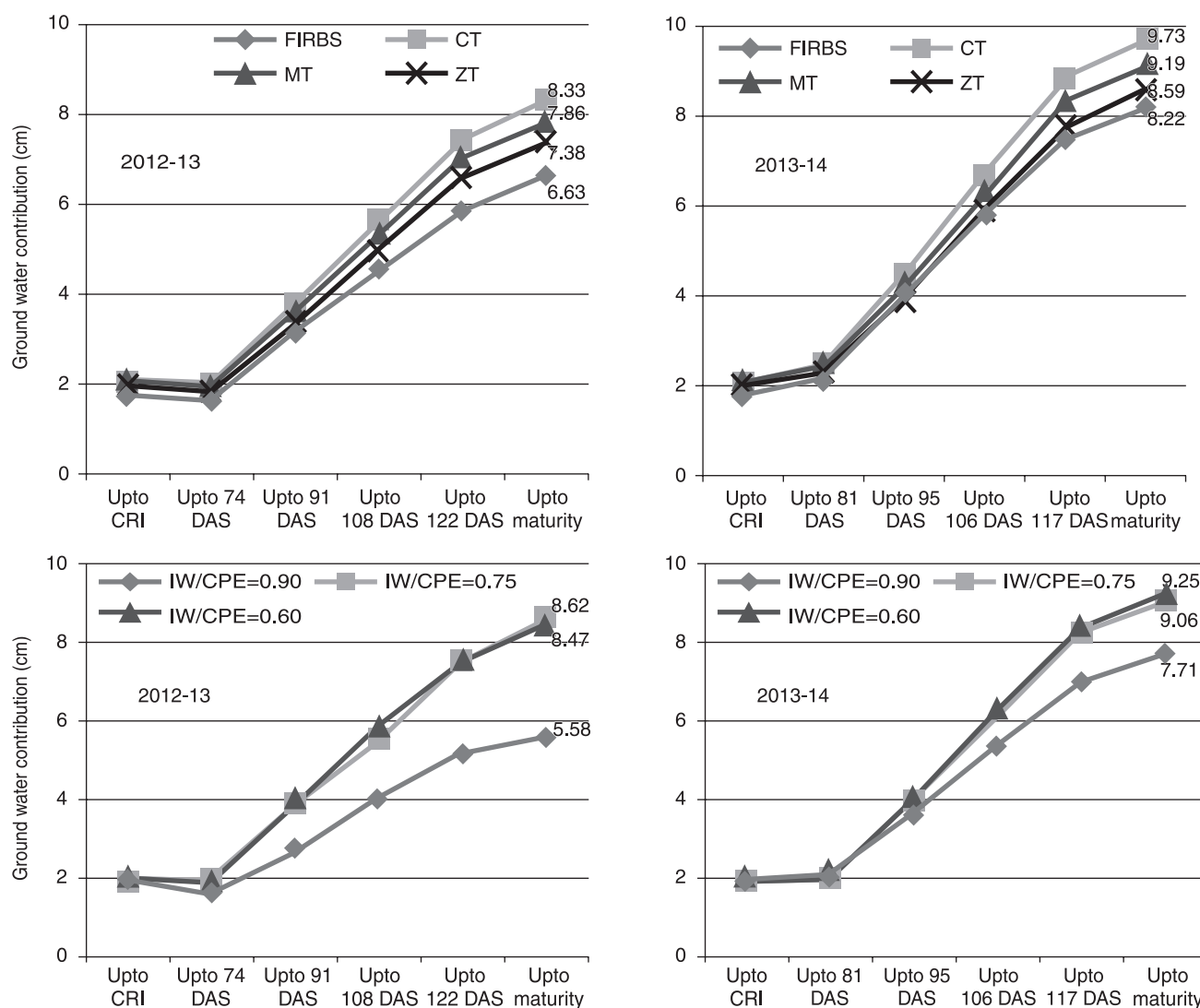


Fig 2 Cumulative ground water contribution (cm) in wheat 2012–13 and 2013–14.

16%, 12% and 6% in 2013–14 under FIRBS, ZT and MT, respectively compared to CT. The soil moisture in terms of GWC by 18–19% and 20–22% contributed towards total water use during two years, which was slightly higher over SMD. CT and ZT in wheat had the highest ground water contribution towards crop ET due to increased crop growth, by increased crop ET, requiring higher amount of moisture. Uptake of water from soil increased by developing a gradient for upward movement and higher hydraulic conductivity resulted in increased moisture uptake from lower to upper soil layers (Mc-Garry *et al.* 2000). Lower contribution of ground water in FIRBS due to efficient utilization of available soil moisture indications reduced upward flux from shallow water table.

Among the irrigation schedules, cumulative GWC was maximum with irrigation at I_2 (8.62 cm) followed by I_3 (8.47 cm). The contribution of ground water with I_1 (5.58 cm) was least by 34% over I_2 with for all the growth periods during 2012–13. In 2013–14, the higher GWC obtained under I_3 and lowest in I_1 . Overall, higher moisture regime of IW:CPE=0.90 resulted in lower ground water

use compared to lower moisture regimes during both the years. Higher moisture regimes of irrigation at IW:CPE=0.90 resulted in lower ground water use over others in both the years. Irrigation applied at lower moisture regimes or deficit irrigation poses yield reduction up to 5 to 10% by utilizing the ground water to meet the crop water demand.

Irrigation water: The total amount of irrigation water applied was lowest in FIRBS compared to CT, MT and ZT, the amount for a particular irrigation was bifurcated in different crop periods within the land configuration techniques. Higher amount of irrigation water applied in CT, MT and ZT over FIRBS in both the years, and the contribution towards total water use was highest by 43.2% and 35.6% in two years over FIRBS. Overall, ZT treatment used 0.5–0.7 cm less water over conventional tillage. In IW:CPE=0.90, three irrigations at CRI, 74 DAS and 122 DAS with a total amount of 17.08 and 17.14 cm were applied in the respective years. While, in other treatments, two each irrigations with 11.43 and 11.44 cm, and 11.39 and 11.41 cm applied in I_2 and I_3 , in respective years. The irrigation water contribution towards consumptive water

use was higher by 41.8% and 43.6% had recorded in IW:CPE=0.90 over other two irrigations during 2012–13 and 2013–14, respectively. Overall, the contribution in the form of irrigation and rainfall accounts 30–35% each observed towards total water use by the wheat crop, and least towards SMD and GWC.

Consumptive use of water: The period wise water use by crop from depletion from soil, rainfall, contribution from shallow ground water and post sown irrigations in both the years was highest in CT followed by MT and ZT from CRI to anthesis stage (Fig 3). While, lowest water was consumed by wheat crop under FIRBS. The total consumptive water use by the wheat was around 12%, 6% and 2% lower in 2012–13 and 9%, 5% and 2% lower in 2013–14 under FIRBS, ZT and MT, respectively compared to CT. Likely, an average of 22% to 54% irrigation water could be saved in bed-planting of wheat over conventional system (Idnani and Kumar 2013). Planting of wheat crop under FIRBS resulted in 2–3 cm less total water (CU) use compared to CT (Fig. 3). Zero tillage wheat utilized lowest total water

use by 1.5–2 cm and irrigation water by 0.5 cm over conventional tillage. It clearly showed that the required water for crop ET was supplied by increased soil moisture depletion and use of ground water under zero tillage. The relative per cent contribution of different components of CU varies with ZT, MT, CT and FIRBS of irrigation water by 34.8>34.7>34.2>33.7%; GWC by 20.4>19.8>19.2>18.6% under CT, MT, ZT and FIRBS; and SMD by 17.4, 16.9, 16.5 and 15.8%, respectively during 2012–13. During 2013–14, the percent contribution of different components was similar in various land configuration techniques with slight variation in percentage values.

Among the irrigation schedules, maximum amount of water used under moisture regime of IW:CPE=0.90 over others in 2012–13. The total water used was around 8% and 7% lower under IW:CPE=0.75 and IW:CPE=0.60 compared to IW:CPE=0.90. In 2013–14, the total water used around 9% lower under IW:CPE=0.75 and IW:CPE=0.60 over IW:CPE=0.90. Collectively, maximum water in wheat used in IW:CPE=0.90 over other two irrigation schedules.

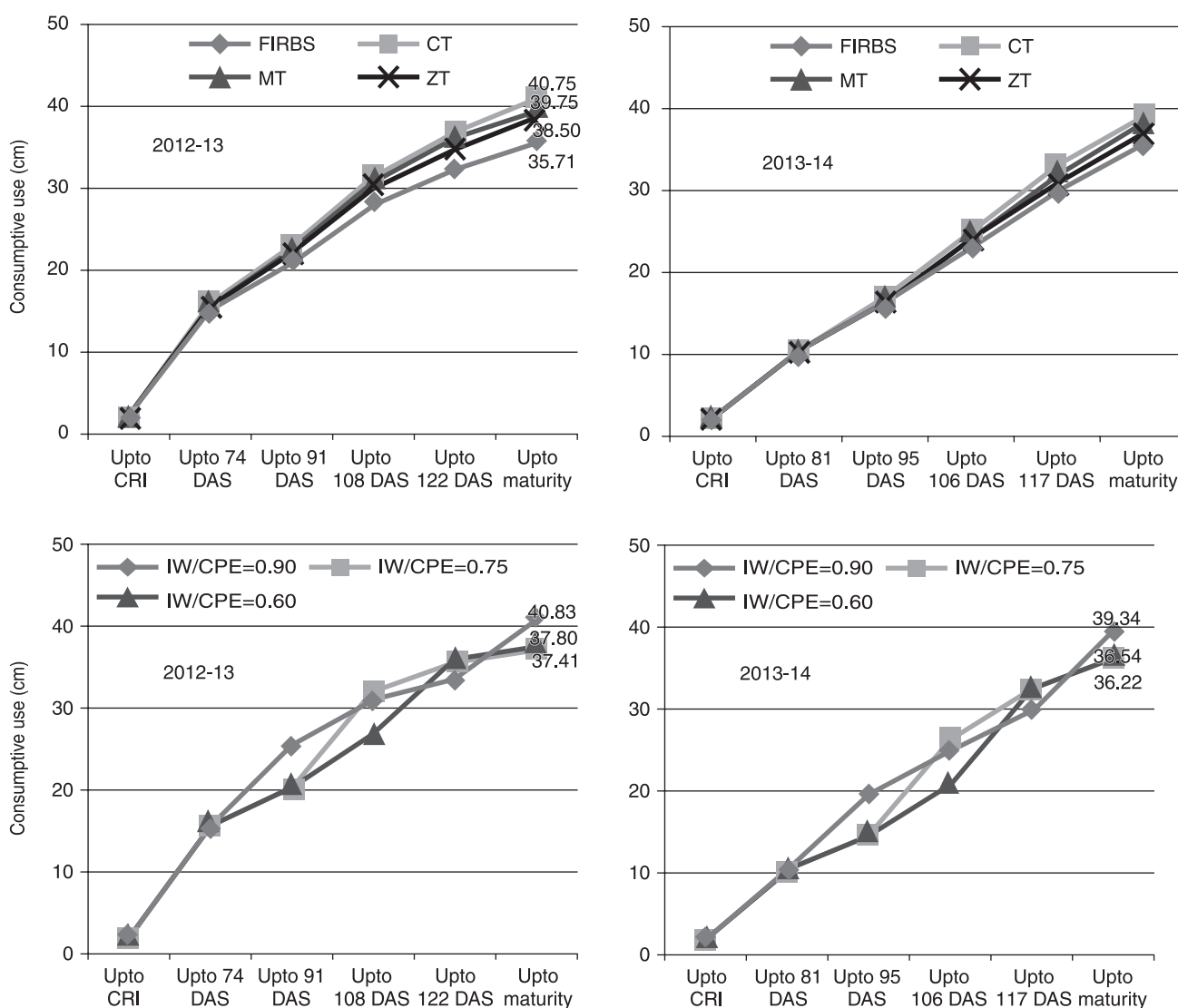


Fig 3 Cumulative consumptive use of water in wheat during 2012–13 and 2013–14.

In both the years, the irrigation contribution was highest by 41.8% and 43.6% under IW:CPE=0.90 over other 2 irrigation treatments. Compared to lower irrigation levels, IW:CPE=0.90 had lowest GWC by 13.6% and 19.6%, and SMD by 16.7% and 16.9% in respective years. The increased CU with increase in number of irrigations might be due to the fact that surface layers under higher frequency of irrigations remained wet for a longer duration thereby creating the condition for higher rate of evaporation as compared to lower frequency of irrigations (Rajanna *et al.* 2018).

Water use efficiency (WUE) and irrigation water productivity (WP_i): For the seasons 2012–13 and 2013–14, significantly higher WUE obtained in FIRBS (14.5 and 15.5 kg/ha/mm, respectively) over other land configuration techniques (Table 3). In 2012–13, WUE was 38.8% higher in FIRBS over MT, and in 2013–14 it was higher by 35.7% over CT. Similarly ZT plots had highest WUE by 6.5% to 26.0% over CT and MT in both the years. The WP_i followed the same trend as WUE in both the seasons. However, FIRBS had significantly higher WP_i by 42.8% compared other techniques in 2012–13 and slightly lower WP_i of 38.3% was recorded in 2013–14 in FIRBS over others (Table 3). ZT plots had significantly higher WP_i by 21% and 26% in two years over CT and MT. Enhanced hydraulic conductivity, more filled pores in FIRBS enables soil moisture availability in the root zone for longer period and hence higher yield and WUE (Bharambe *et al.* 1999). The primary reason for higher WP_i in FIRBS may be assigned to less evaporation under less wetted surface area compared to others.

Application of irrigation at IW:CPE=0.75 had highest WUE (12.9 and 14.0 kg ha⁻¹mm⁻¹) and WP_i (4.2 and 4.4 kg m⁻³) in respective seasons over two irrigation levels (Table 3). However, least WUE by 8.1% and 7.5% showed in IW:CPE=0.60 compared to IW:CPE=0.75 in the respective crop seasons. An account of 45.8% and 43.3% highest WP_i was recorded in IW:CPE=0.75 over higher moisture regimes of IW:CPE=0.90 in both years because of relatively better grain yield coupled with less amount of irrigation water applied in the respective plots.

Growing degree days (GDD), heat units and heat use efficiency (HUE): Maintaining higher GDD, heat units and heat use efficiency were essential to reach maturity during all the crop growth seasons. Knowledge of accumulated GDD can provide an estimate of harvest date as well as crop development stage (Ketring and Wheles, 1989). Our study showed that, significantly higher GDD obtained in ZT and FIRBS over other land configuration techniques in both the years (Table 1). Significantly higher GDD was recorded in CT and MT till spike initiation stage in 2012–13 in comparison with FIRBS and ZT. In 2013–14, no significance difference observed among the land configuration techniques to accumulate GDD. Wheat growth proceeds towards anthesis and milking stage, increasing the accumulation of GDD significantly under ZT and FIRBS in both the years. The GDD and heat unit accumulation went on increasing from spike initiation to physiological

maturity of the wheat crop. In general, ZT plots accumulated significantly higher GDD (3288°C day and 3321°C day) over CT and MT, but ZT was at par with FIRBS in both the years, respectively. More availability of soil moisture in all the growth stages encourages wheat crop to grow profusely by intercepting and accumulating solar energy, and leads to higher GDD and HUE. Changes in seasonal temperature affect the productivity through the changes in phenological development process (Kajla *et al.* 2015).

Various land configuration techniques had not influenced significantly on heat units or heliothermal units at spike initiation stage during 2012–13 and 2013–14 (Table 2). On an average, wheat crop took 130 days to accumulate 20000 to 22000°C day hours in all the techniques. Moreover, FIRBS and ZT plots accumulated 1000°C day hour additional heat units till maturity over CT and MT in both the years. In 2012–13, conventional tilled plots had highest HUE in terms of grain yield over FIRBS, ZT and MT (Table 3). Interestingly in 2013–14, FIRBS planted wheat had highest HUE, slightly followed by ZT compared to CT and MT.

Among the irrigation schedules, no significance difference observed on accumulated GDD in spike initiation stage in both the years. At all the growth stages, the accumulated GDD was maximum in irrigation applied at IW:CPE=0.90 over other two irrigation levels during 2012–13 and 2013–14 (Table 1). However, irrigation applied at IW:CPE=0.90 recorded highest HUE over other irrigation schedules in both the years (Table 3). This clearly showed that application of irrigation at IW:CPE=0.90 to wheat crop helps in attaining better growth by mitigating heat or high temperature stress through maintaining higher soil moisture. Winter crops are especially vulnerable to thermal stress particularly in reproductive phase and differential response of temperature change to various crops has been noticed under different production environment (Kalra, 2008). The heat use efficiency depicted a positive linear relation with grain yield of wheat with $R^2 = 75.5$ ($y = 0.0424x + 0.1438$, $R^2 = 0.755$) in 2012–13 and $R^2 = 71.0$ ($y = 0.0338x + 0.1828$, $R^2 = 0.7102$) in 2013–14.

Planting of wheat in FIRBS resulted in 2–4 cm (2–4 lakh litres) less water use to complete maturity over MT and CT. In FIRBS system with a higher moisture regime (IW:CPE=0.90), grain yield, WUE and WP_i, accumulation of GDD, heat unit and HUE were higher than others. Although highest grain yield obtained in FIRBS, the SMD, GWC and total consumptive use was lowest over other land configuration techniques. However, ZT also produced at par grain yield, WUE, and WP_i, accumulation of GDD, heat unit and HUE with FIRBS. Under drought or moisture stress conditions in the long term, the adoption of FIRBS and ZT with deficit irrigation at IW:CPE=0.90 is an inventive method that can increase wheat yields with minimum water use in semi-arid conditions of India.

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