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# Water budgeting in major *rabi* crops under surface irrigation in Western Indo-Gangetic Plains

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ABSTRACT

A water budget confers the relationship between input, output and changes in the amount of water at an individual farm level to the watershed level depending upon point of interest. Basic components of water budgets are precipitation, evapotranspiration, change in soil moisture storage, deep percolation and runoff. However, non-availability of water balance parameter is the main problem for achieving the more crop per drop. Therefore, the current study was undertaken at ICAR-Indian Agricultural Research Institute, New Delhi farm (Mid-block, MB) during *rabi* 2016-17 to study the water budget of different major *rabi* crops (wheat, mustard, chickpea) under surface irrigation. Water budget components like soil moisture were measured by gravimetric method periodically, and daily crop-evapotranspiration (ETc) and stage-wise effective rainfall (Pe) for the test crops were estimated using FAO-CROPWAT- 8.0 model. Irrigation scheduling was done on the basis of soil moisture depletion method and total volume of water applied measured through star flow meter. The total volume of irrigation water applied during the entire crop period was 337.75, 211.54 mm and 182.90 mm, for wheat, mustard and chickpea, respectively. The results revealed that both in late- and timely - sown mustard (MB-3A-1 and 3A-2), chickpea (MB-9-A) and wheat crops (MB-3A-3, 6-A and 12-A), the highest ETc was recorded during mid-season stage (i.e. 82.90, 79.50, 94.07, 126.04, 114.02, 132.61 mm, respectively). The deep- percolation losses varied from 29.3-31.8 % for sandy loam soil to 40.2-42.2 % for clay loam soil under different crops due to larger amount of irrigation water applied in clay soil. These water budgeting parameters are location and crop specific and so to be estimated for crops, seasons and regions.

**Key words:** Deep percolation, Effective rainfall, Evapotranspiration, *Rabi* crops, Surface irrigation, Water budgeting

India faces the problems of low irrigation efficiency and under-utilization of irrigation water potentials in one way, in other way enhancing cost of production including cost for pumping water, diminishing farm profits, inefficient water management, declining groundwater table are some of the major challenges faced by the farmers in the north-western (NW) India and Indo-Gangetic Plains. The increasing water scarcity and mismanagement of the available water resources are the major threats to sustainable development for the various sectors, especially domestic, industrial and agricultural. It is estimated that Indian farmers use 2 to 4 times more water to produce a unit of major food crop than in China or Brazil (Dhawan 2017). Therefore, India is facing a major challenge on the water front. Its current per capita water availability 1544 $m^3$/year, has already fallen below the cutoff point of 1700 $m^3$, adding India to the list of water stressed nations. This situation is likely to worsen further unless drastic reforms are undertaken to manage scarce water resources more efficiently and in a sustainable manner. And, the reforms must start from water use in agriculture as it consumes about 80% of freshwater resources available in the country. As water is likely to be a more binding constraint to Indian agriculture than even land, thus the focus has now been on raising agricultural productivity per unit of water. Total utilizable water resource of India (after 40 % of evapotranspiration losses) is 1123 $m^3$, of which about 61% is surface water and the remaining 39% groundwater (Suhag 2019). Considering the per capita water availability as an indicator, 'water stress' has already begun in India and given the projected increase in population by the year 2025, the annual per capita availability is likely to drop to the level of water scarcity (Poddar *et al.* 2014). However, availability of water per capita fresh water is major concern as the population continues to increase in future (Mall *et al.* 2006). Considering the per capita water availability as an indicator, 'water stress' is beginning to show in India and given the projected increase in population by the year 2025, the annual per capita availability is likely to drop to the level of water scarcity (Poddar *et al.* 2014). Thus there

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is a tough challenge before the agricultural sector to produce more food from less water, which can be achieved by increasing crop water productivity (Zwart and Bastiaanssen 2004; Mohammed *et al.* 2018; Dass *et al.* 2015).

Realizing the current status of increasing gap between irrigation potential created and utilized, the Government of India has launched an irrigator welfare and booster scheme Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) during 1st July 2015 (Wani *et al.* 2017), in a focused manner to achieve convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of precision-irrigation and other water saving technologies. It is an umbrella term covering the vision of 'Har Khet Ko Pani' and 'More Crop per Drop' to boost the efficiency of present irrigation operation system. In this perspective, National Water Mission had also set one of its goals in 2011 to increase water use efficiency (WUE) by 20%, and to reduce by half the gap of about 15% between the irrigation potential created and utilized by the year 2017 (Hussain 2004). The objective decided under PMKSY looks like a cup of tea, but in real it is not as simple as. Therefore, for making PMKSY a success, detailed study on water budgeting is very much required.

The accounting of water resources, downscaling from national and regional to individual fields or farms level, is necessary which can be done by using water balance approach for optimizing water resources. Water resource management requires knowledge of the processes influencing the water budget at the catchment scale or watershed basis. Water balance is an important part of the hydrological studies. Understanding the magnitude and dynamics of various components of water balance is essential for better understanding the fate of soil water and to develop technological options for viable management of water resources (Mohammed *et al.* 2018). Comprehensive knowledge of inflow parameters like precipitation (mm), amount of irrigation (mm), upward flux (mm), outflow parameters like surface runoff (mm), water loss by deep percolation (mm), evapotranspiration (ET) (mm) is needed (Sudhishri and Patnaik 2004; Sudhishri *et al.* 2007) and their difference must be equal to change in soil moisture storage between planting and harvesting of the crop. ET is a major component of hydrologic cycle and its accurate forecasting is essential in all water-resource applications (Falamarzia *et al.* 2014). The soil water loss by drainage also represents a considerable portion, highlighting the importance of this component in soil water balance studies, especially in soils with a sandy texture. However, surface runoff does not contribute significantly to the calculation of the soil water outflow on farm water balance basis. A rainfall with high intensity causes higher runoff, while a well-distributed rainfall of low intensity produces the soil water infiltration and drainage (Feltrin *et al.* 2009). Water balance approach is a simple mass balance law that takes into account of all sources and sinks of water that effects soil and surface water storage. This approach uses minimum input requirements and parameters while still retaining reasonable predictive accuracy (Boers *et al.* 1994). A water budget is an accounting of the rates of water movement and the change in water storage in all or parts of the atmosphere, land surface, and subsurface (Healy and Winter 2007). Although simple in concept, water budgets may be difficult to accurately determine. It can be calculated for a single irrigation event, on a weekly or monthly basis, or even annually. Modelling and/ or monitoring water balance at field scale has also a wide variety of applications, such as performing economical and hydrological analysis of on-farm reservoirs. However, non-availability of water balance parameters is the main problem for achieving the objective of more crop per drop. The Indo-Gangetic Plain (IGP) of India is an important region for agricultural production and food security contributing to 50% of the total food grain production and supporting food security of about 40% population (Pal *et al.* 2009). However, the unsustainable increase in agricultural production through indiscriminate use of external inputs gradually led to the deterioration of agri-environment and natural resources in the region (Erenstein *et al.* 2007). The growing threat of food insecurity and poverty in the region is further exacerbated by the risk of climate change and variability in agricultural production. There would be at least 10% increase in irrigation water demand with a 1°C rise in temperature (Sivakumar and Stefanski 2010). Again the rapid increase in the number of tube wells during last four decades in north-western IGP has resulted in overexploitation of groundwater, leading to a rapid fall in water tables (Sapkota *et al.* 2015). During *rabi* season, wheat is the major crop of the IGP except West Bengal. The total area covered by the crop is 67% of the agricultural area of the IGP, which is almost equal to that of the rice crop. With this backdrop, experiment was conducted at ICAR-Indian Agricultural Research Institute (IARI) farm, representative of western Indo-Gangetic Plains to study various water budget components in major *rabi* crops.

## MATERIALS AND METHODS

The experiment was conducted at the ICAR-IARI research farm, mid-block (MB) fields MB-3A, 6A, 9A and 12A . The study site is located at 28°38'29.76" N latitude 77°09'31.68" E longitude and 220.6 m above the mean sea level.

*Climate and weather condition:* The climate of the study site is classified into semi-arid and sub-tropical climate with hot and dry summer and cold winters. The mean annual temperature is $25^0$C, whereas the mean annual rainfall is 1127.7 mm of which 74 % occurs during monsoon season (June to September). Winter showers are also common during December-March but the amount, intensity and duration are very uncertain. *Rabi* (October-March) crops are mainly raised under irrigation. The average relative humidity during the experimental period varied from 39-95%. The average wind speed varied from 0.7- 13 kmph. Mean daily evaporation ranged 1.4-8.2 mm/day. The meteorological data for the crop growing season was obtained from Agromet Observatory of Division of Agricultural Physics, ICAR-IARI, New Delhi.

*Characteristics of experimental plots:* The field MB-3A is situated at higher elevation in comparison to other plots and there is gentle gradient in land from MB-3A towards MB-12A. The crops like wheat, mustard and chickpea sowed in different fields and detail information about field, sowing time harvesting time and respective field area were sown in Table 1. Since there are three crops in MB-3A, so it was divided into MB-3A-1, MB-3A-2 and MB-3A-3.

*Soil properties:* The soil of experimental field belongs to order Inceptisol, Mehrauli series having clay loam texture in upper 0-15 cm and sandy clay loam for 15-30 cm and sandy loam for 30-45 cm of depth. The depth of water table remained below 3.5-meter-deep during the crop growing period from ground surface (Amir Jan, 2015). A soil samples from three different locations at an individual field were collected from all the experimental fields before the start of growing season for analyzing texture and moisture content. The soil texture of the field MB-3A and MB-6A are found to be sandy loam to sandy clay loam, whereas MB-9A and MB-12A are varied from clay loam to clay. The first field, i.e. MB-3A was consisting of 3A-1, 3A-2, 3A-3 which was under late sown mustard, normal mustard and wheat crop respectively, whereas, MB-6A, MB-9A and MB-12A were under wheat, chickpea and wheat, respectively.

*Field water budgeting*

Water budgeting is defined as:

Inflow = outflow ± change in storage

whereas, Inflow = effective precipitation + irrigation + upward flux

Outflow = evapotranspiration + runoff + deep percolation or deep drainage;

Soil water storage was computed by using FAO water balance formula of different component (Allen *et al.* 2006)

$$\Delta S = Pe + I + ET - D$$

where, ΔS = change in storage (mm); P = rainfall (mm); IW = irrigation water applied (mm); R = runoff (mm); ETc = crop evapotranspiration (mm); D = deep percolation (mm).

Since, the selected field was closed bunded, so surface runoff was negligible. Hence surface runoff assumed as zero.

*Inflow measurement*

Effective rainfall (Pe) was calculated by using CROPWAT 8.0 software.

*Irrigation water measurement*

Irrigation scheduling was done as per the soil moisture depletion method (Mohammed *et al.* 2018). To find out moisture stored in the root-zone, periodically collection of soil sample was carried out from the field from different depths of 0-15cm, 15-30cm, 30-45cm and 45-60cm in case of wheat, whereas the depth extended up to 60-90cm in case of mustard and chickpea as per depth of effective root-zone by using gravimetric method and then moisture content was calculated.

Irrigation water applied as per moisture content status in effective root zone depth and stages of crop, which was determined at any time by Time Domain Reflectometer (TDR) that was calibrated previously using the gravimetric method (Michael 2008). Rooting depth was identified by digging the soil and then through root sampler.

$$SMD = (\theta_{Fc} - \theta_i) \times DRZ \times Bd$$

where, SMD: soil moisture deficit (mm), $\theta_{Fc}$: soil water content at field capacity (%), θi: soil water content before irrigation (%), DRZ: root zone depth (mm), Bd: bulk density of soil (t/m$^3$). Daily rainfall data were collected from a rain gauge located at about 1 km southeast of the experimental plots. Effective rainfall was calculated using standard methods given by FAO and then total water use was computed as the sum of water applied through irrigations and effective rainfall. Irrigation water measurement was carried out with the help of star flow meter. The star flow meter is a sensor based; 12-V battery logged mechanical devices, which measures the discharge as well as cumulative volume with time and date. Under field condition to know how much water reached at head of field channel area velocity methods was adopted at different straight reaches for definite length of reach. Overall average flow rate and period of irrigation was taken for further analysis.

Table 1 Details about the experimental field, crops and Kc values

| Field No | Soil texture | Crops | Duration (Days) | Area (m$^2$) | Growth stages | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Initial | Developmental | Mid-season | Late season |
| MB-3A-1 | Sandy loam | Late-sown mustard* | 126 | 7765 | 0.27(25) | 0.59(36) | 1.04(40) | 0.5(25) |
| MB-3A-2 | Sandy loam | Timely-sown mustard* | 155 | 3050 | 0.27(30) | 0.59(35) | 1.04(45) | 0.5(45) |
| MB-3A-3 | Sandy loam | Wheat | 140 | 10115 | 0.7(20) | 0.93(27) | 1.15(55) | 0.325(38) |
| MB-6A | Sandy clay loam | Wheat | 141 | 17900 | 0.7(25) | 0.93(24) | 1.15(52) | 0.325(40) |
| MB-9A | Sandy clay loam | Chickpea | 126 | 18915 | 0.4(25) | 0.7(29) | 1.0(40) | 0.35(32) |
| MB-12A | Clay loam | Wheat | 132 | 20412 | 0.7(20) | 0.93(26) | 1.15(54) | 0.325(32) |

Data in parenthesis shows the duration of growth stages in days; *Generally, In North India early September to mid-October is for Early sown mustard, whereas December is for late sown mustard.

*Measurement of outflow*

*Actual crop-evapotranspiration (ETc)*

For the determination of actual ET, the knowledge of reference ET and Kc value is necessary. So by using CROPWAT-8.0 software (based on Penman Montheith method) reference ET was estimated for respective crop duration. The value of Kc for different crop with stage-wise was obtained from FAO Irrigation and Drainage paper no-56. ETc was calculated from following formula;

$$ETc = Kc \times ET_O$$

where; ETc = Actual crop-evapotranspiration (mm); Kc = Crop coefficient; $ET_0$ = Reference evapotranspiration (mm).

*Kc value*: The Kc values of different crops for different growth stages, namely, initial stage, developmental stage, mid-season stages and late season stage are calculated by taking reference from FAO Irrigation and Drainage paper no-56 have been given in Table 1. For most of the studied crops, it was found that for mid-season stages the Kc value is higher because of fully grown and maximum coverage of ground surface.

*Duration of growth stages:* To find out crop coefficient (Kc) for different crops at different growth stages the duration of growth period must be known. Hence, the fields were frequently visited for identifying different stages of growth and their length. The observed duration of growth mostly matched with the duration reported in FAO drainage paper no-56 with slight variation. The observed duration of different growth stages and their length of time are shown in the Table 1.

*Measurement of change in soil moisture storage*

Change in moisture storage was determined by measuring moisture content periodically, and also before and after each irrigation.

*Deep percolation (D)*

Deep percolation can be defined as the net amount of water, infiltrated into soil and moved beyond the crop root zone. USDA (2005) defined deep percolation (D) as the portion of water that percolates below the influence of the effective root zone (ERZ). Deep percolation (P) was calculated by rearranging the water budgeting equation (Upreti *et al.* 2015)

$$D = Pe + I + ETc \pm \Delta S$$

where, D = deep percolation; Pe = effective rainfall; I = depth of irrigation water applied; ETc = crop-evapotranspiration; ΔS = change in storage.

## RESULTS AND DISCUSSION

*Irrigation water applied*

The seed drill sown fields MB-6A, MB-9A and MB-12A had a large basin size, while MB-3A-1, MB-3A-2 and MB-3A-3 were grown in a number of small check. The results showed that five numbers of irrigations were provided in all wheat fields excluding pre-sowing irrigation while for mustard and chickpea irrigated twice apart from pre-sowing irrigation. It was found that the highest total volume of water applied in wheat field MB-6A while lowest volume was applied in chickpea. The total amount of water applied in chickpea was 182.99 mm (MB-9A) including one pre-sowing and two post-sowing irrigation at 27 and 79 DAS which was found to be coinciding with the finding of Reddy and Ahlawat (1998).

*Depth-wise volumetric soil moisture variations*

Overall average moisture content (percentage volumetric basis) in wheat field at 0-15 cm varied from 19.41% for MB-3A to 28.6 % for MB-12A, while for 6A it was 20.18%. The depth wise percentage variation of moisture content for MB-6A during the whole crop season for 0-15 cm was 4.0 % higher than MB-3A-3, while for the depths 15-30, 30-45, 45-60 cm and 60-90 cm it was 14.2, 11.4, 33.4 and 13.1%, respectively. MB-12A had 47.7, 60.6, 54.2 % and 26.3% higher moisture content compared to MB-3A-3 (sandy loam soil) which was at higher elevation as compared to other wheat fields, i.e. MB-6A (Sandy clay), and MB-12A (Clay Loam) (Fig 1).

*Effective rainfall*

The rainfall amount and distribution were quite erratic during the experimentation period. The total amount of rainfall during November to April was 89.9 mm; monthly maximum rainfall occurred during January followed by March. The maximum effective rainfall 57.2 mm occurred in January. There was no effective rainfall in November, December and February. Further, total number of rainy days during the crop growing period was 6. The maximum one-day rainfall (57.4 mm) occurred on 27 of January.

*Crop evapotranspiration (ETc)*

Stage wise as well as total ETc that were estimated for different wheat fields, MB-3A-3, MB-6A and MB-12A; mustard fields, i.e. MB-3A-1, MB-3A-2 and chickpea field, MB-9A had a variation that were basically due to differences in the period of different growth stages, cultivar and variation in dates of sowing. The estimated daily ETc of wheat for MB-3A-3, MB-6A and MB-12A was found to be 0.71, 0.9 and 0.8 mm/day, respectively, during initial stage, whereas maximum daily estimated ETc was found 4.30 mm/day (96 DAS), 4.0 mm/day (99 DAS) and 4.7 mm/day (86 DAS) respectively for mid-season stage which was found in close agreement with the experiment conducted by Tyagi *et al.* (2000) for determination of daily as well as seasonal ETc of wheat at Karnal district of India (Table 2 and 3). However, the average ETc for whole growing season of wheat was found to be 254, 236.5 and 243.1 mm which were slightly lower than ETc estimated by Tyagi *et al.* (2000). The total seasonal ETc of chickpea during the investigation was found to be 176.9 mm which was slightly lower that the finding

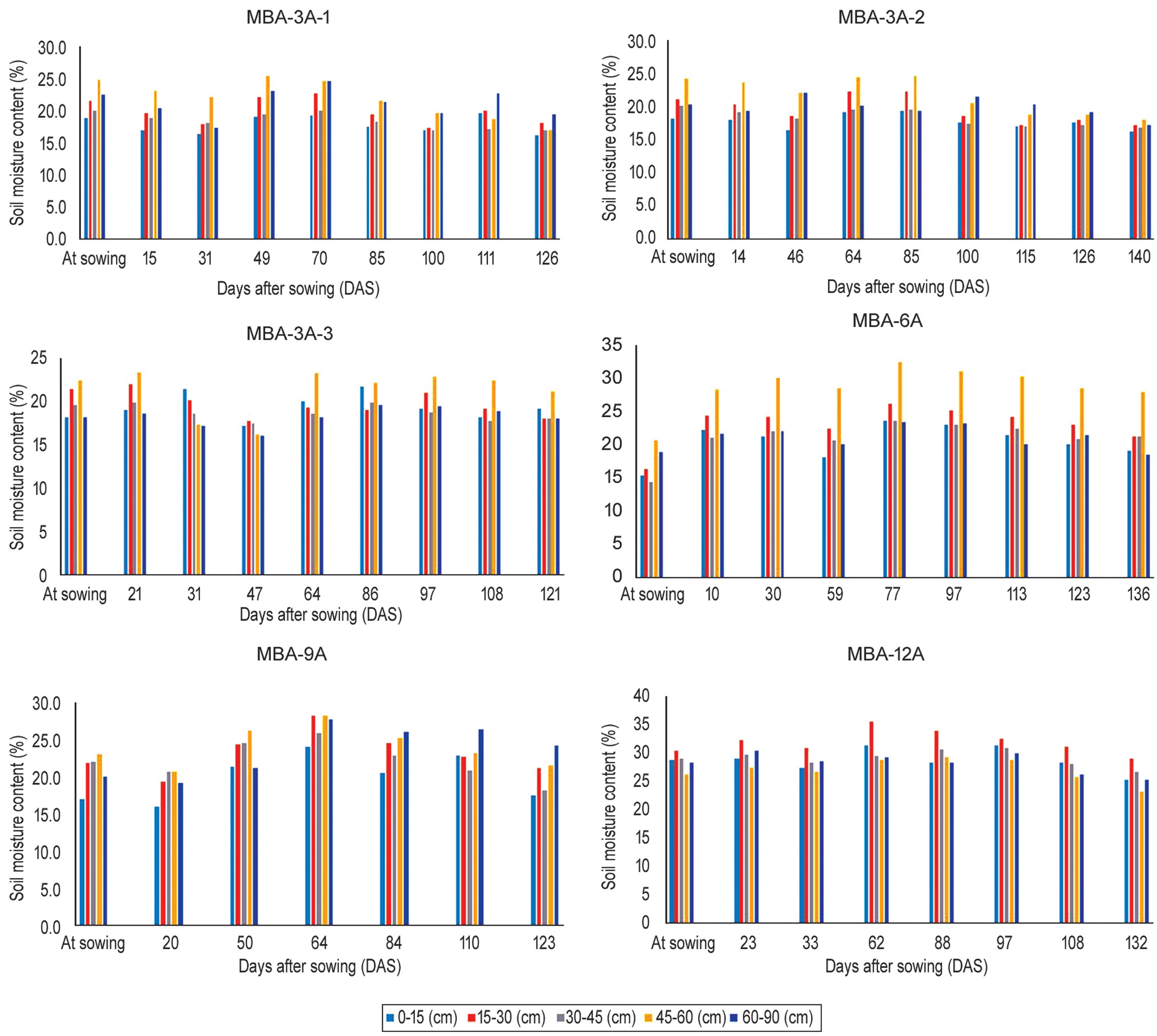


Fig 1 Depth-wise volumetric soil moisture variation during the experiment in different fields.

of Jalota *et al.* (2006), i.e. at least 181 mm in loamy sand and 176 mm in sandy loam soils.

*Deep percolation*

Estimation of deep percolation rate revealed a positive relationship between crop rooting characteristics and irrigation regimes. The deep percolation was found higher during the initial stage while it decreased with subsequent irrigation because of increase in the effective root length with growing periods. Overall deep percolation varied from 58.33 mm for MB-9A (chickpea) to 146.40 mm for MB-6A (wheat). Deep percolation for mustard field was intermediate between the wheat and chickpea fields. The average daily rate of deep percolation was the highest for MB-6A (1.09 mm/day) and among wheat field it was the lowest for MB-3A-3 (0.69 mm/day) while for MB-12A deep percolation rate was 0.70 mm/day. The average daily rate of deep percolation in mustard ranged from 0.56 mm/day to 0.71 mm/day. The percentage variation in total deep percolation *w.r.t* total water applied at field was higher for MB-3A-1 (42.16 %) and lowest for MB-3A-3 (29.35 %), while other fields fell under medium category. The percentage loss in deep percolation in other crop field like MB-9A, MB-12A, MB-6A and MB-3A-2 was 31.89, 29.82, 40.19 and 41.29%, respectively. Similar results have also reported by Martinez *et al.* (2008) who suggested that as a general trend, effective root zone depth of wheat varied from 65-75 cm in medium to heavy compacted soil. Zhang *et al.* (2004) found that most of the root system of wheat during the growth period was concentrated in the upper 40 cm of soil. Kirkegaard and Lilley (2007) reported that the maximum rooting depth usually occurs at about anthesis or shortly thereafter for wheat and at late-flower to late-pod stages for oilseeds and pulses (Liu *et al.* 2011).The minimum deep percolation was found in MB-9A (chickpea) field due to clay loam texture of soil, less application of irrigation water at 27 DAS and 79 DAS, fast growth rate of root before flowering and continued up to maturity (i.e. 55 cm/cm$^2$).

Total depth of deep percolation during the entire cropping season was approximately similar for both late sown mustard and early sown mustard in MB-3A-1 and MB-3A-2, respectively. During late season stage, mustard of both different sowing dates, were under water-stressed condition. Hence, during this stage deep percolation found to be negative (mathematically), practically this was assumed to be zero (Tables 2 and 3). Though, wheat crop in MB-3A-3 belongs to sandy loam texture but deep percolation was found to be minimum among other two field (MB-6A and MB-12A) which belongs to sandy clay loam and clay loam, because of lining of main channel and shorter length of lateral channel. In contrast, the other two have large length of main conveyance channel.

## *Conclusion*

The water balance is a location and crop specific and so to be estimated for different crops across seasons and regions. Water balance for same crop may vary for different region due to complex inter-action of climatic and physiographic parameters. Deep percolation (D) can be decreased by applying less depth of water in each irrigation

Table 2 Stage-wise and overall water budgeting for late-sown mustard, timely mustard crop and chickpea

| Field No | Crops | Stage | I (mm) | Pe (mm) | ETc (mm) | ΔS (mm) | D (mm) |
|---|---|---|---|---|---|---|---|
| MB-3A-1 | Late-sown mustard | Initial | 69.3 | 0.0 | 13.0 | 20.8 | 35.6 |
| | | Developmental | 70.2 | 7.3 | 38.9 | 5.9 | 32.6 |
| | | Mid-season | 72.4 | 41.6 | 82.9 | 10.0 | 21.2 |
| | | Late season | 0.0 | 16.3 | 23.1 | -5.9 | 0.0 |
| | | Total | 211.9 | 65.2 | 157.9 | 30.7 | 89.3 |
| MB-3A-2 | Timely-sown mustard | Initial | 64.4 | 0.0 | 16.8 | 19.3 | 28.2 |
| | | Developmental | 71.7 | 7.3 | 34.8 | 9.8 | 34.3 |
| | | Mid-season | 75.2 | 47.5 | 79.5 | 16.3 | 26.9 |
| | | Late season | 0.0 | 16.3 | 31.4 | -12.9 | 0.0 |
| | | Total | 211.2 | 71.1 | 162.6 | 32.5 | 89.4 |
| MB-9A | Chickpea | Initial | 53.6 | 0 | 18.0 | 26.9 | 8.8 |
| | | Developmental | 65.0 | 4.9 | 17.3 | 8.8 | 43.8 |
| | | Mid-season | 64.2 | 42.6 | 94.1 | 7.0 | 5.8 |
| | | Late season | 0.0 | 16.3 | 47.5 | -7.1 | 0.0 |
| | | Total | 182.9 | 63.8 | 176.9 | 35.5 | 58.3 |

Irrigation water applied; Pe: Effective rainfall; ETc: Crop evapotranspiration; ΔS: Change in storage; D: Deep percolation

Table 3 Stage-wise and overall water budgeting for wheat crops

| Field No | Crops | Stage | I (mm) | Pe (mm) | ETc (mm) | ΔS (mm) | D (mm) |
|---|---|---|---|---|---|---|---|
| MB-3A-3 | Wheat | Initial | 111.1 | 0.0 | 22.1 | 26.7 | 62.3 |
| | | Developmental | 53.9 | 4.9 | 43.2 | 5.4 | 10.2 |
| | | Mid-season | 107.9 | 61.9 | 126.0 | 24.2 | 19.6 |
| | | Late season | 55.8 | 12.6 | 62.6 | 1.4 | 4.4 |
| | | Total | 328.7 | 79.4 | 254.0 | 57.6 | 96.5 |
| MB-6A | Wheat | Initial | 112.8 | 0.0 | 36.4 | 27.4 | 49.1 |
| | | Developmental | 65.6 | 0.0 | 30.9 | 2.2 | 32.5 |
| | | Mid-season | 122.8 | 47.5 | 114.0 | 11.5 | 44.7 |
| | | Late season | 63.1 | 16.3 | 55.2 | 4.0 | 20.1 |
| | | Total | 364.3 | 63.8 | 236.5 | 45.2 | 146.4 |
| MB-12A | Wheat | Initial | 101.1 | 0 | 22.7 | 21.7 | 56.7 |
| | | Developmental | 55.9 | 4.9 | 39.8 | 3.2 | 17.8 |
| | | Mid-season | 112.9 | 54.7 | 132.6 | 28.3 | 6.6 |
| | | Late season | 51.2 | 12.6 | 48.0 | 1.1 | 14.6 |
| | | Total | 321.0 | 72.2 | 243.2 | 54.3 | 95.8 |

Irrigation water applied; Pe: Effective rainfall; ETc: Crop evapotranspiration; ΔS: Change in storage; D: Deep percolation event with increasing irrigation frequency. Another way to reduce deep percolation is applying less depth of irrigation in initial growth stage and increasing the depth with increasing root depth in crop life cycle. This information can be used for better water management in other similar regions of India.

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