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In-situ soil water dynamics under different irrigation methods in North East India

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ABSTRACT

Availability of in-situ soil water plays a major role in exploiting the potential yield of crops under irrigated conditions. Depending on type of irrigation, variations of soil water is mostly observed at different soil depths within the root zone. The deviation of soil water at the edaphic zone becomes a deciding factor in assuring optimum yield. As availability of irrigation water is a great concern during non-rainy season, water saving irrigation techniques need to be adopted to maximize the productivity under hilly terrain. An experiment was laid out with potato as a test crop under the valley region of Meghalaya plateau on sandy clayey soil to study in-situ soil water dynamics under three different irrigation methods viz. furrow, micro-sprinkler and gravity-fed drip. Irrigation was scheduled at every weekly basis to restore back the soil water required to achieve the field capacity. Mean value of soil water up to 15 cm depth was 21.75, 22.65 and 23.45%, however, range (minimum to maximum) was 16.21-29.17; 15.56-29.21 and 17.84-28.97% for furrow, micro-sprinkler and gravity-fed drip irrigation, respectively. Co-efficient of variation was found to be the maximum (4.65%) for furrow over other two types of irrigations during the weekly interval. Deviation of in-situ soil water was found to vary rapidly at upper layer (30 cm) under furrow method of irrigation; but at deeper soil layer rapid variation was not observed. Water use efficiency of potato was evaluated to be 14.66, 18.78, 20.63 kg ha^{-1} mm^{-1} for furrow, micro-sprinkler and gravity-fed drip irrigation, respectively.

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INTRODUCTION

Water saving irrigation methods is the tools for sustaining crop production under scenario of climate change coupled with water scarcity. To increase food production and cropping intensity, winter crops need to be taken up under assured irrigation. Though blessed with high annual rainfall, North Eastern Hill (NEH) region of India faces water crisis during non-rainy seasons. Apart from rice, potato based cropping system is observed in certain pockets of NEH zone. Potato is grown in an area of 18,173 ha producing 1,81,089 metric tonnes with an average yield of 9.9 t ha^{-1} for NEH states of India, which is rather low in terms of per hectare (ha) yield as compared to all-India average of 22.72 t ha^{-1} (Saxena and Mathur, 2013). Potato is sensitive to the water stress and soil water fluctuation than other crops. There was a wide variation of in-situ soil water content with varied irrigation methods reported by Saikia (2011). The in-situ soil water status was found to be better, when less amount and more frequent irrigation water application was applied both in top and deeper layer of soil. Soil water plays a major role in hydrological and ecological processes at the land surface, including infiltration, runoff, erosion, solute transport, and land-atmosphere interactions (Chen *et al.,* 2010). It exerts a high degree of variability in space and time and influenced by factors i.e. topography, soil, vegetation, land uses, precipitation. Considering variation of soil water, yield and quality of the produce also varies drastically in water sensitive and exhaustive tuber crop like potato. High potato tuber quality was reported when the availability of water is optimum with minimum variation was observed in soil water content in the root zone (Alva *et al.,* 2012). The sensitivity to water stress is most often explained by relatively shallow root system of the potato crop and low root to shoot ratio, which limit its capacity to extract water and nutrients from the soil. Potato production can be increased by suitable irrigation schedule throughout the growing period (Chauhan and Ambast, 2014). Due to shallow root system, erratic rainfall and inadequate irrigation water supply, potato crop generally suffered from transit water stress (Thiele *et al.,* 2010). Test crop was poatao, (*Solanum tuberosum* L.), is the one of the most important cash crop North Eastern hill region of India. The per capita consumption of this region is similar to the European country. Simultaneously, the potato productivity in this land lock region is very low and almost half of the national average. So many factors have been responsible for poor yield of potato including lack of adequate water management (Singh *et al.,* 2015).

MATERIALS AND METHODS

A field trial was taken up with three irrigation methods viz. furrow, micro-sprinkler and gravity-fed drip with potato as a test crop at the experimental farm of the College of Postgraduate Studies, Umiam, Ri-Bhoi district of Meghalaya during winter season of 2015-16. The experimental site is situated at 91°18' E longitude and 25°40' N latitude and at an

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altitude of 950 m above the mean sea level. The location of the experimental site is shown in Fig 1. The physico-chemical properties of the top soil were analysed using standard protocol and presented in Table 1.

The textural classification of experimental soil comes under sandy clay loam type with a bulk density of 1.36 g cc^{-1}. The soil is acidic with a pH value of 4.4. The soil is rich in organic carbon of 1.60% and potash (275 kg ha^{-1}), however, available N and P was found to be in the medium range. Three different irrigation methods were practiced to find out soil moisture dynamics and also the response of irrigation on potato crop.

Soil moisture characteristics curve was prepared using a pressure plate apparatus to find out the available range of soil moisture (Fig. 2). Soil moisture contents at field capacity and permanent wilting point are 29.3 and 8.66%, respectively. The in-situ soil water status was recorded by gravimetric method at weekly interval by taking soil samples from different soil depth viz. 0-15, 16-30, 31-45 and 45-60 cm from different irrigated treated plots through soil augur during growing season (Jalota *et al.*, 1998). The soil moisture content (MC) was calculated using the Eq. 1.

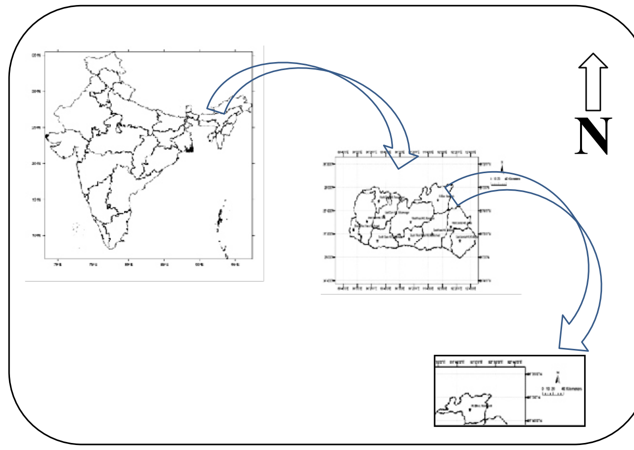


Fig. 1: Location of the experiment

$$MC = \frac{M_1 - M_2}{M_2} \times 100 \text{....Eq. 1.}$$

Where, MC = In-situ soil water content (%); M1 = Mass of initial soil sample (g); M2 = Mass of over-dry soil sample (g).

Table 1: Physico-chemical properties of experimental soil

Soil property	Recorded Value	Interpretation	Method of analysis
Physical properties			
Sand (%)	60.90	Sandy clay loam	Buoyoucos Hydrometer method (Chopra and Kanwar,1976)
Silt (%)	16.66		
Clay (%)	22.44		
Bulk density (g cc^{-1})	1.36		Core method (Black,1965)
Field capacity (%)	29.34		Pressure plate method (Noorbakhsh and Afyuni, 2000)
Permanent wilting point (%)	8.66		Pressure plate method (Noorbakhsh and Afyuni, 2000)
Chemical properties			
Available N (kg ha^{-1})	229.97	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	14.35	Medium	Bray and Kurtz's method (Jackson, 1973)
Available K_2O (kg ha^{-1})	275.03	High	Flame photometer method (Jackson, 1973)
Organic carbon (%)	1.60	High	Walkley and Black's method titration method (Walkley and Black, 1934)
Soil p^H	4.44	Acidic	Systonic glass electrode P^H meter (Jackson, 1973)

The mean minimum and maximum temperature during cropping ranged between 10.75-24.28°C, and mean relative humidity ranged from 50.19-78.92% during evening and morning hours, respectively. The total pan evaporation and rainfall during the crop period was calculated to be 374.30 and

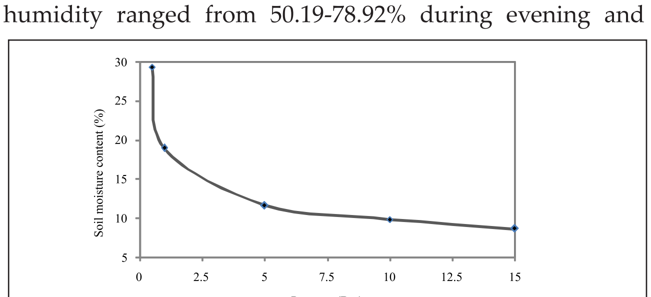


Fig. 2: Soil moisture characteristics curve of the soil at the study area

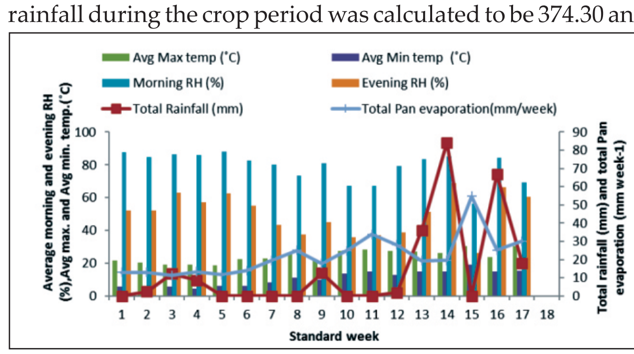


Fig.3: Weekly weather data prevailed during crop season

243.2 mm, respectively. The weekly weather data prevailed during crop growing season is shown in Fig.3.

Irrigation water was supplied by pumping water from a nearby sump using an electric pump of 0.5 hp capacity. Quantification of irrigation water was done by volumetric measurement. The average discharge of the pump was recorded using a bucket of 200 litre capacity and by time keeping method volume of water discharged to a respective plot was evaluated. Prior to the experiment the volume of water discharge was calculated and presented in Table 2. The average discharge capacity of the pump was calculated to be 48.5 liter per minute.

Table 2: Discharge of the electric pump used for irrigation

Time (min)	Total amount of water (l)	Discharge (l min^{-1})
1	45.6	45.6
2	109.2	54.6
4	182.4	45.6
3	143.4	47.8
2	97.8	48.9
	Average	48.5

Scheduling of irrigation was done every weekly basis to restore the amount of water depleted in the period. The in-situ soil moisture was calculated from the soil sample collected at suitable depths from different irrigation plots. The amount of water applied (WA) for irrigation was calculated using the formula given in Eq. 2.

$$WA = \sum_{i=1}^{4} \frac{F_c - M_{cbi}}{100} \times 100 \times BD_i \times RD_i \quad \text{....Eq. 2.}$$

Where, WA = water applied, cm; Fc = field capacity of soil (%); Mcbi = moisture content of soil before irrigation (%); BDi = bulk density of soil at ith layer (the value of "i" ranges from 1-4) and RDi = root zone depth of ith layer.

Total four layers of soil water content was considered and the water extraction pattern by the plant was assumed to be in 40, 30, 20 and 10% for the top to bottom four layers, respectively (Michael, 2005). To evaluate the efficacy of different irrigation treatment the field water use efficiency (WUE) was evaluated using the formula given in Eq. 2.

$$WUE = \frac{Yield}{WR} \times 100 \quad \text{....Eq. 2.}$$

Where, WUE = water use efficiency (kg ha^{-1} mm^{-1}); Yield (kg ha^{-1}); and WR= water requirement (mm).

RESULTS AND DISCUSSION

Rainfall and irrigation water applied

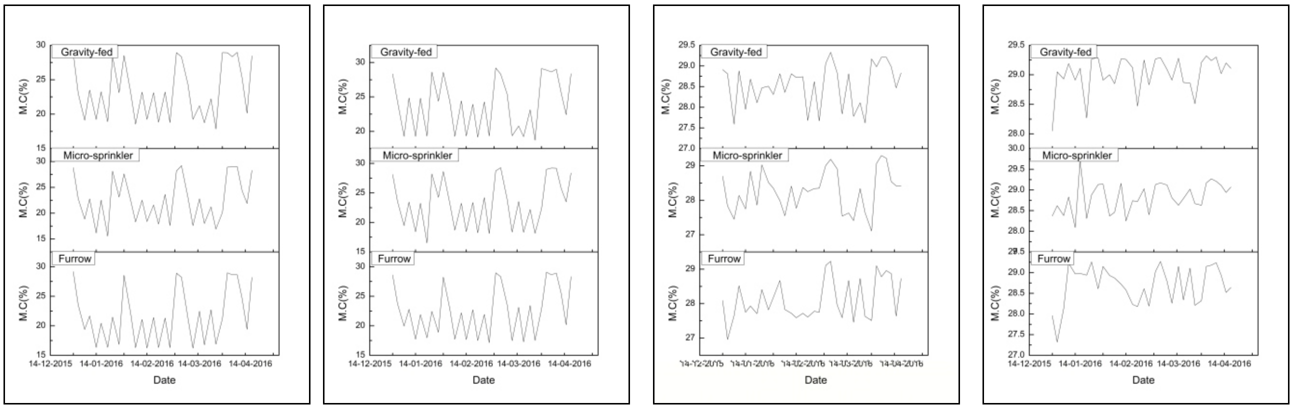
Soil water requirement was evaluated based on amount of water depleted on weekly basis. The average depth of water applied on weekly basis for furrow, micro sprinkler and gravity-fed drip was 5.5, 5.0 and 4.6 cm, respectively during growth stage. Total number of irrigation provided to the crop was 10 during the growth period. The amount of water applied during the crop growing period was calculated to be 78.55, 75.99 and 70.38 cm, out of which the effective rainfall was 6.5, 6.65 and 6.65 cm for furrow, micro-sprinkler and gravity-fed drip irrigation, respectively. During crop growing season, total amount of rainfall received was 24.3 cm, and only around 25% was utilised effectively by crop. At the end of crop maturity, during harvest a good amount of rainfall was received during 16th and 17th standard meteorological week (SMW) amount to 84.9 mm, which was not utilised by crop.

Moisture content of soil and its variation

Moisture content of the soils from different depths was recorded according to the date and necessary amount of water was applied to meet demand of potato. Average, minimum and maximum value (range) and co-efficient of variation (CV) of soil water at four different depth for different irrigation treatments is presented in Table 3. The moisture dynamic curves at four different depths for three different irrigation methods are shown in Fig 4. Soil water contents in furrow irrigation was observed highest among the other two different irrigation methods and variation was rapid within 0-15 and 16-30 cm and comparatively less within 31-45 and 46-60 cm of the soil depth. The range of soil water variation within 0-15, 16-30, 31-45 and 46-60 cm was 16.21-29.17%, 17.13-29.03%, 26.96-29.23% and 27.32-29.27%, respectively. In micro-sprinkler irrigation, and gravity-fed drip irrigation, in the upper layer the soil water content was found to be always above 15% more than the fifty percentage of moisture depletion of the soil and again under gravity-fed drip irrigation the fluctuation was found to be smooth due to localised application of irrigation water. The gravity-fed drip system generally operates with the force of gravity and has a greater relevance in the hilly terrain (Ray *et al.,* 2014). Though potato cultivation was mostly practised with furrow method of irrigation, however performance was found to be at par

Table 3: Average, range and co-efficient of variation of soil water at four different depth for different irrigation treatments

Irrigation method	Soil moisture at 0-15 cm depth (%)				Soil moisture at 16-30 cm depth (%)				Soil moisture at 31-45 cm depth (%)				Soil moisture at 46-60 cm depth (%)			
	Mean	Range		CV	Mean	Range		CV	Mean	Range		CV	Mean	Range		CV
		Min.	Max.			Min.	Max.			Min.	Max.			Min.	Max.	
Furrow	21.75	16.21	29.17	4.65	22.57	17.13	29.07	4.12	28.11	26.96	29.23	0.58	28.70	27.32	29.27	0.46
Micro-sprinkler	22.65	15.56	29.21	4.34	23.37	16.51	29.27	4.03	28.28	27.11	29.30	0.59	28.83	28.09	29.31	0.36
Gravity-fed-drip	23.45	17.84	28.97	3.92	24.00	18.71	29.21	3.78	28.54	27.59	29.33	0.51	29.02	28.05	29.32	0.31



0-15 cm 16-30 cm 31-45 cm 46-60 cm

Fig. 4: Variation of soil water at different depth

when potato was planted in raised bed and periodical earthening up was done at appropriate time during the period of tuber formation. The formed tuber was not exposed to direct sunlight and was always kept under loosened soil (Scott and Suarez, 2011).

The depletion of soil water in the upper layer of the soil varies more than 50% of available soil water for furrow type of irrigation as reported by Dey (2016). Dynamics of soil water with reference to the variation of topography and land usage was also reported by workers mostly carried out their field research work under undulating topography (Xie *et al.,* 2012). Under undulating topography the soil water content at upper layer depletes more rapidly as compared to deeper soil layer, however, under base flow conditions with terraced cultivations sometimes the soil water dynamics may take a reverse order. In Meghalaya, study was taken up under a valley experiment land where there was no base flow and dynamics of soil water was found more at upper layer compared to layer below.

Crop Performance

Significant difference in performance of crop as influenced by different irrigation treatments. Among treatments gravity-fed drip (14.52 t ha^{-1}) yielded highest tuber yield over furrow method of irrigation (11.56 t ha^{-1}) but was found at par with micro-sprinkler irrigation (14.27 t ha^{-1}). Treatment plots under gravity-fed drip (25.61%) and micro-sprinkler (23.44%) produced more tubers, respectively over furrow method of irrigation as presented in Table 4.

Table 4: Effect of irrigations on tuber yields (t ha^{-1})

Treatment	Tuber yield (t ha^{-1})
Furrow	11.56
Micro-sprinkler	14.27
Gravity-fed drip	14.52
S.E.(m) ±	0.55
C.D.(P = 0.05)	2.15

The performance of potato crop under micro sprinkler was reported to be better over furrow method of irrigation as reported by Singh *et al.* (2010). However, reports on deficit and drip irrigation system with potato were encouraging with higher yield and lower water usage (Xie *et al.,* 2012). Though field experiment was carried out with a gravity-fed drip irrigation system the performance of crop was found superior in terms of yield and WUE over other two methods of irrigation. Water use efficiency (WUE) under different irrigation methods were calculated at time of harvest by dividing yield with total amount water used (Table 5). Significant result was recorded among irrigation treatments for field WUE maximum field water efficiency was recorded for gravity-fed drip (20.63 kg $ha^{-1}mm^{-1}$) compared to furrow irrigation (14.66 kg $ha^{-1}mm^{-1}$) but at par with micro-sprinkler (18.78 kg ha-1mm^{-1}). Among the irrigation treatments WUE for gravity-fed drip and micro-sprinkler irrigation was calculated to be 40.72% and 28.10% advantage, respectively over furrow method of irrigation.

Table 5: Effect of irrigations on field water use efficiency (kg ha^{-1} mm^{-1})

Treatment	Field water use efficiency (kg $ha^{-1}mm^{-1}$)
Furrow	14.66
Micro-sprinkler	18.78
Gravity-fed drip	20.63
S.E.(m) ±	0.73
C.D.(P = 0.05)	2.85

The results obtained for WUE of potato were found in the range as reported by Xie *et al.,* 2012).

Conclusions

From the field study on soil water depletion within four different depths viz. 0-15, 16-30, 31-45 and 46-60 cm for three irrigation methods was observed to be different. Highest depletion of soil water was recorded in furrow irrigation followed by micro-sprinkler and gravity-fed drip irrigation. However, depletion was found to be rapid in the upper layer compared to the lower soil depths. The amount of water applied during the crop growing period was calculated to be 78.55, 75.99 and 70.38 cm for furrow, micro-sprinkler and gravity-fed drip irrigation, respectively. Higher WUE recorded for gravity-fed drip among three irrigation methods followed by micro sprinkler and furrow method of irrigation. Gravity-fed drip irrigation may be suggested as a suitable irrigation technique where soil water depletion was found less and uniform water applied for higher yield and better economy.

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