Estimation of Water Use Efficiency and Economics of Potato Varieties under different Methods of Irrigation

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Abstract

The study was conducted during November, 2015 to April 2016 in the research farm of College of Post-graduate Studies, Central Agricultural University, Umiam, Meghalaya, India. The experiment was done under split plot design (SPD) with tree replications and the potato was planted in flat bed by maintaining a spacing of 50×20 cm^2 in a plot size of 4×3 m^2 to find out water use efficiency (WUE) and economics (gross return, net return, benefit cost ratio) of the potato varieties under different irrigation methods, where, three different irrigation methods viz., furrow irrigation (I_1), Micro-sprinkler irrigation (I_2) and Gravity-fed drip irrigation (I_3) as a main plot treatments and four different varieties viz., Kufri Jyoti (V_1), Kufri Megha (V_2), Kufri Giriraj (V_3) and Kufri Giridhari (V_4) as sub-plot treatments. From the experiment it was found that the highest WUE was recorded under Gravity-fed drip irrigation (I_3) but was at par with the Micro-sprinkler irrigation (I2), among the varieties it was for Kufri Megha (V_2) but was at par with Kufri Jyoti (V_1) and Kufri Giriraj (V_3). In terms of economics, highest gross return, net return and benefit cost ratio (BCR) was recorded under Gravity-fed drip irrigation (I_3) but it was at par with Micro-sprinkler irrigation (I_2), among the varieties highest gross return, net return and BCR was recorded under variety Kufri Megha, which was at par with the varieties Kufri Jyoti (V_1) and Kufri Giriraj (V_3).

Keywords: SPD, WUE, economics, irrigation methods, potato varieties

1. Introduction

Potato (*Solanum tuberosum* L.) is the world's fourth most important food crop with a total production of 370 mt from 19 m ha of land after rice, wheat and maize (FAO, 2013). Potato, originated from Peru and Bolivia (South America), is cultivated around the globe, and for India potato cultivation is practised for last 300 years (Singh et al., 2008). For vegetable purpose, it has become one of the most popular crops in the country; it is used in day to day food menu of almost all Indian recipe irrespective of rich and poor, hence, it is also known as "poor man's friend". Potato is rich in vitamins, proteins, carbohydrates, enzymes and other substances necessary for human nutrition. Potato contains 20.6% carbohydrate 2.1% protein, 0.3% fat, 1.1% crude fibre and 0.9% ash on dry weight basis (Singh et al., 2008). Apart from daily usage as vegetable, it is also used for several industrial purposes, viz., production of starch, alcohol, dextrin, glucose, dyes etc.

Potato crop prefer temperate climate for best growth and mostly grown during *rabi* season, but it can also be cultivated successfully under sub-tropical areas. It thrives best under short day condition coupled with abundant sunshine and cool nights. Potato can be grown under a wide range of soils, i.e., sandy loam to heavy clay. However, well drained sandy loam soils are well suited for higher yield. It grows well in a pH ranging from 5.5 to 6.5 (Prasad, 2015).

Developing countries are responsible for more than half of the total world potato production in the world (FAO, 2009). Among the developing countries, India is the second largest potato producer in the world after China. Potato plants are more sensitive to water stress and soil water fluctuations than other crops (Onder et al., 2005; Jabro et al., 2012). High potato production with high tuber quality was reported when the availability of water is optimum with minimum variation in soil moisture content. This sensitivity to water stress is most often explained by the relatively shallow root system of the potato plant and by the low root to shoot ratio, which limit its capacity to extract water and nutrients from the soil (Harris, 1992). In many areas, potato regularly suffers transient water stress due to erratic rainfall or inadequate irrigation techniques (Thiele et al., 2010).

In India, potato is grown almost in all states. Major potato growing states are Himachal Pradesh, Punjab, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, West Bengal, Bihar and Assam. Among these states, Uttar Pradesh, West Bengal, Bihar and Punjab together account for about 86% of Indian's potato production. The production and productivity of potato is quite gloomy in the hilly states of north eastern India.

Meghalaya a North-Eastern (NE) states of India enjoys varied climates, viz., tropical to alpine, sub-tropical in the *Jaintia* and *Khashi* hills and tropical climates in the *Garo* hills. The nature of the soil also varies from clay to loam in most part of the valley, whereas in the hill areas, soils are mostly lateritic in nature with pH ranging from 4.7 to 6.8 most suitable for potato cultivation. Potato crop is cultivated in the hills during autumn and spring season without proper water management practices (i.e., some places as rain-fed; some places with little irrigation or no irrigation). Potato an exhaustive and water sensitive crop lack of optimum irrigation during the growing season definitely have an adverse impact on the output, which ultimately affect economics of the potato growers. It 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 this hilly states of NE India, which is rather low in terms of ha^{-1} yield as compared to all-India average 22.72 t ha^{-1} (Saxena and Mathur, 2013).

One of the major constraints of low productivity of potato in Meghalaya may be attributed due to the lack of optimum water availability during the growing season specially moisture sensitive stage like emergence, tuber initiation and stolon formation stage, which affect the crop yield in the state. Being a water sensitive crop potato gives good response while cultivated with assured irrigation. Meghalaya, receives good amount of annual rainfall, i.e., to a tune of around 250 cm but most of the rainfall (85%) is received only during the monsoon seasons and creates water deficit situation during the non-rainy seasons (Khan et al., 1987). For better potato production, it is required to have an assured supply of irrigation water with suitable irrigation techniques during the potato growing seasons. Suitable irrigation practices can help the farmers to have judicious usages of irrigation water for potato, which not only save good amount of irrigation water but also increase the yield. Along with suitable irrigation practices the performance of potential potato varieties need to be ascertained. Different irrigation methods, i.e., furrow method (mostly popular among the farmers), micro-sprinkler methods, gravity-fed drip methods, along with some promising potato varieties, i.e., Kufri Jyoti, Kufri Megha, Kufri Giriraj, Kufri Giridhari were put under trial to find out the yield advantage, water use efficiency and cost-benefit analysis of cultivation practices under different varietal and irrigation combinations. The potato varieties, i.e., Kufri Jyoti, Kufri Megha, Kufri Giriraj, Kufri Giridhari were chosen for the experiment, because these are the potential potato varieties released by Central Potato Research Institute (CPRI), Shimla, for the north-eastern hill regions (Pandey et al., 2008), hence, the performance of different potential potato varieties may be studied under the mid hill of Meghalaya to find out the water use efficiency and economics under different methods of irrigation.

2. Materials and Methods

The details of material used, experimental procedure followed and techniques adopted during the course of investigation are described in this section.

2.1. Site of the experiment

The experiment was carried out at the experimental farm of the College of Post Graduate Studies, (CAU), Umiam, Ri-bhoi district of Meghalaya, India during 2015-16 *rabi* season. The experimental site is situated at 91˚18′ E longitude and 25˚40′N latitude and at an altitude of 950 m (MSL). The location of the experimental site is shown in Figure 1.

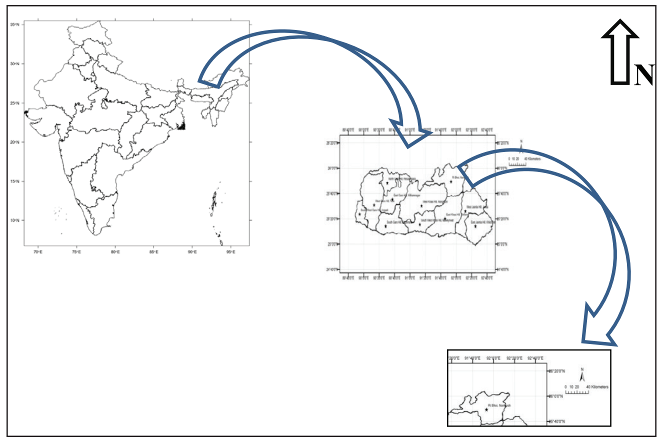

Figure 1: Location of the experiment

2.2. Soil characteristics

Soil samples were collected randomly from the top 0-60 cm for physical analysis and 0-30 cm for chemical analysis from several spots of the experimental site and mixed thoroughly to make composite sample. The mechanical and chemical analyses were carried out to determine the physico-chemical properties of the soil and the results are presented in Table 1.

Table 1: Physico-chemical properties of experimental soil

Soil Property	Value	Interpretation	Method of analysis
1. Soil physical property			
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		Coremethod (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)

Continue...

Soil Property	Value	Interpretation	Method of analysis
2. Soil chemical properties			
Available N (kg ha^{-1})	229.97	Medium	Alkaline potassium permanganate method (Subbiah and Asisa, 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 (%)	1.6	High	Walkley and Black's method titration method (Walkley and Black, 1934)
Soil P^{H}	4.44	Acidic	Systonic glass electrode PH meter (Jackson, 1973)

The soil of the experimental site is sandy clay loam in texture. Organic carbon and potassium content were high but nitrogen and phosphorous content were medium and it is also noted that the soil of the experimental site is acidic in reaction (Singh et al., 2007) with field capacity (29.34%), permanent wilting point (8.66%) and bulk density 1.36 g cc^{-1}.

2.3. Details of the experiment

Potato as a test crop was grown in a strongly acidic Alfisol of Meghalaya, North East India (NEI), with three irrigation methods as main treatment and four potato varieties as sub treatment.

The field experiment was replicated thrice under Split Plot Design (SPD). The schematic layout of the plan of experiment is described in Figure 2.

2.3.1. Details of the treatment combination

Experimental plots were prepared with suitable plot site of 12 m^2 (4 m×3 m^2). Each plot was separated from other by a suitable bund of 50 cm and partitioning was performed with 250 µ polythene sheet up to 60 cm depth, so that the plots were hydrologically separated from each other. The details of experiment are presented in Table 2. The experimental layout is shown in Recommended doses of N, P and K=120: 80: 80 kg ha^{-1} (Full doses P and K were applied at the time of sowing along with 50% of N and rest 50% of N at tuber initiation stage through top dressing) along with Farmyard manure @ 15 t ha^{-1}. FYM was applied 15 days before sowing of potato for proper decomposition. The nutrients N, P and K were supplied through the chemical fertilizer Urea, Single super phosphate and Murate of potash, respectively. Standard agronomic practices were followed during crop growth period

Table 2: Detailed of the experiment

Design:	Split Plot Design (SPD)
No. of treatments:	12
No. of replication:	3
Total No. of plots	36
Plot size	4×3 m^2
Spacing	50×20 cm^2
Bund size	50 cm (partitioning by 250 µ polythene sheet up to 60 cm depth)

Experimental Layout: N ↑

Replication-1		Replication-2		Replication-3	
I_1V_2	I_1V_3	I_2V_3	I_2V_2	I_3V_4	I_3V_3
I_1V_4	I_1V_1	I_2V_1	$I2V_4$	I_3V_1	I_3V_2
I_2V_2	$I2V_4$	$I1V_4$	I_1V_1	I_2V_1	I_2V_3
I_2V_1	$I2V_3$	I_1V_2	$I1V_3$	I_2V_4	I_2V_2
I_3V_1	I_3V_4	I_3V_2	I_3V_1	I_1V_1	I_1V_3
I_3V_3	I_3V_2	I_3V_4	I_3V_3	I_1V_4	I_1V_2

I: Irrigation, V: variety;

Figure 2: schematic layout of the experimental field

Treatment details

A. Main treatments	B. Sub treatment
I.Furrow Irrigation (I_1)	Kufri Jyoti (V_1)
II. Micro-sprinkler (I_2)	II. Kufri Megha (V_2)
III. Gravity-fed drip irrigation (I_3)	III. Kufri Giriraj (V_3)
	IV. Kufri Giridhari (V_4)

and crop was harvested at maturity.

2.4. Methods of irrigation application

There were three methods of irrigation applied to the experimental plots according to their treatments and the detail descriptions of the three different irrigation methods are given below.

2.4.1. Furrow method

Furrow irrigation was given by making small parallel channels along the field length in the direction of predominant slope. Water was applied at the upper reach of the slope, so that the total field can be irrigated under the influence of gravity.

2.4.2. Micro sprinkler method

Micro-sprinkler method of irrigation was a method of applying irrigation water which was similar to rainfall. Water was distributed through a system of pipes and sprinkler heads placed on the field according to the requirement. The water was usually given by pumping. It was then sprayed into the air and irrigate entire soil surface through spray heads so that it breaks up into small water droplets which fall to the ground.

2.4.3. Gravity-fed drip method

Gravity-fed drip irrigation, was an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of many different plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. But in my research we applied water without mixing fertilizers by maintain constant 6 m water height for the appropriate flow of the water through pipeline laid near to the root zone of the potato crop. It was done through narrow tubes (drippers) that deliver water directly to the base of the plant or root zone. Here, pumping of water is nullified and the water was applied by putting a bucket of 50 litre capacity at a static head of 6 meter.

2.5. Water use efficiency (WUE)

It is the dry matter produced per unit of water and it is expressed as kg ha-mm^{-1}. The detail of the WUE is described in Equation 1.

Field water use efficiency**:**

It is the ratio of crop yield (Y) to the total amount of water used in the field (WR). It is calculated by following equation.
WUE (Field)=Y (kg)÷WR (mm)

Yield Estimation (Y):

From each plot harvested potato was calculated in kg ha^{-1} by multiplying it with suitable factors.

2.6. Dry matter accumulation plant^{-1}

The destructive sample was recorded six times at 15 days interval from 15 DAS onwards.

One plant from each plot (not the tagged one) was selected randomly, after washing properly, *i.e.,* after removal of foreign particles, excess moisture was removed with the help of blotting paper. The plant after separating as root, stem, leaves, stolon and tubers were weighed for taking fresh weight. After that, it was kept in the oven for about 48 hrs at 60 ^{o}C till a constant weight was obtained. The dried weight were recorded and kept for further observations.

2.7. Tuber yield (t ha^{-1})

Total tuber yield was calculated by excluding the yield of the plant from boundary but by including the yield of sample plants and converted into tonnes per hectare using suitable conversion factor. For the present study a conversion factor of (1,666.67) was used.

2.8. No. of tuber plant^{-1}

After harvest of tubers from every plot excluding the plants from boundary but including the tagged plants number of tuber were counted manually.

2.9. Weight of tuber plant^{-1}

After harvest weight of tubers were taken from every plots excluding the boundary plants but including the tagged plants.

2.10. Economic analysis

The economic analysis was done after the harvest of the potato crop for computing BCR, net return and gross return on the basis of prevailing market price of the different items and products used in the research.

2.10.1. Costs of cultivation

In computing the economics, different variable cost items were considered. The cost includes expenditure on ploughing, seed, chemical fertilizers, irrigation system, irrigation, labour charges and miscellaneous at the prevailing market price during 2015-16 and expressed INR ha^{-1} according to the different irrigation methods.

2.10.2. Returns

Utility of adopting different practices was compared by using the following economic parameters:

Gross returns=Tuber yield×local market price of potato tubers

Local market price of the potato tubers were assumed INR 15 kg^{-1}

Net returns=Gross returns–Cost of cultivation

$$\text{Benefit of cost=} \frac{\text{Cross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

2.11. Method of statistical analysis

The data obtained from various studies during investigation were statistically analysed by using the technique of analysis of variance for split plot design over the computer. The difference between the treatment means was tested as for their statistical significance with appropriate critical difference (C.D.) value at 5% level of probability as explained by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Dry matter accumulation plant^{-1}

All the main-treatments gave non-significant results on dry matter accumulation at all the stages of plant growth except at 105 DAS. At 30 DAS, I_3 (3.49 g) accumulated highest dry matter accumulation as compared to I_1 (3.28 g) and I_2 (3.23 g); at 45 DAS, I_2 (5.03 g) dry matter accumulation was highest as compared to I_1 (4.75 g) and I_3 (5.02 g); at 60 DAS, I_3 (7.12 g) had highest dry matter accumulation as compared to I_1 (6.07 g) and I_2 (6.96 g); at 75 DAS similarly, I_3 (20.63 g) accumulated highest dry matter accumulation as compared to I_1 (20.26 g) and I_2 (20.43 g), similar result was found at 90 DAS, as well, where, I_3 (32.64 g) accumulated highest dry matter followed by I_2 (31.39 g) and I_1 (30.39 g) but at 105 DAS I_3 (46.78 g) had significantly higher dry matter accumulation compared to by I_1 (32.46 g) but was at par with I_2 (37.68 g).

The sub-treatments accumulated dry matter significantly at all the stages of plant growth. At 30 DAS, V_3 (3.85 g) had significantly highest dry matter accumulation over V_4 (2.15 g) but was at par with V_1 (3.67 g) and V_2 (3.67 g), at 45 DAS, V_2 (5.39 g) gave significantly highest dry matter accumulation over V_4 (3.96 g) but was at par with V_1 (5.03 g) and V_3 (5.36 g); at 60 DAS, V_2 (7.78 g) were recorded significantly highest dry matter accumulation over V_4 (5.62 g) and V_1 (6.62 g) but was at par with V_3 (6.85 g); at 75 DAS, V_3 (22.46 g) recorded significantly highest dry matter accumulation over V_4 (17.59 g) but at par with V_1 (19.92 g) and V_2 (21.79 g), at 90 DAS V_3 (36.29 g) recorded significantly highest dry matter accumulation over V_4 (22.84 g) and V_1 (31.45 g) but was at par with V_2 (35.33 g); at 105 DAS, V_2 (42.49 g) recorded significantly highest dry matter accumulation over V_4 (26.08 g) and V_1 (38.56 g) but at par with V_3 (40.77 g).

Irrigation water increases plant growth, higher and more numbers of branches, so, potato plant had the higher biomass by expending plant canopy with larger diameter stem and more numbers of leaves (Yuan et al., 2003). At 90 DAS gravity-fed drip irrigation (9.73) had significantly highest leaf number per plant, over, furrow irrigation (9.07) but at par with micro-sprinkler irrigation (9.35), due to the more frequent moisture availability. Among the varieties, significant results were found on number of leaves per plant up to 75 DAS and after that the varieties showed non-significant results on number of leaves per plant, due start of the leaf falling after 75 DAS of the crop (Table 3).

Table 3: Effect of irrigations and varietal treatments on dry matter accumulation plant^{-1}

Treatments	Dry matter accumulation plant^{-1} (g)					
Main treatments (Irrigation)	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Furrow (I_1)	3.28	4.75	6.07	20.26	30.39	32.46
Micro-sprinkler (I_2)	3.23	5.03	6.96	20.43	31.39	37.68
Gravity-fed drip (I_3)	3.49	5.02	7.12	20.63	32.64	40.78
SEm±	0.06	0.23	0.26	1.10	1.45	0.83
CD (*p*=0.05)	NS	NS	NS	NS	NS	3.25
Sub-treatments (Variety)						
Kufri Jyoti (V_1)	3.67	5.03	6.62	19.92	31.45	38.56
Kufri Megha (V_2)	3.67	5.39	7.78	21.79	36.29	42.49
Kufri Giriraj (V_3)	3.85	5.36	6.85	22.46	35.33	40.77
Kufri Giridhari (V_4)	2.15	3.96	5.62	17.59	22.84	26.08
SEm±	0.20	0.32	0.41	1.04	1.18	1.01
CD (*p*=0.05)	0.60	0.96	1.21	3.09	3.54	3.03

3.2. Yield attributes

Data on number of tubers per plant were presented below in table. At the time of harvesting by the total numbers of tubers were counted per plot and dividing that value with total numbers of plant per plot (Table 4).

Non-significant result was found in number of tubers per plant, among the main-treatments I_3 (6.63) had maximum numbers of tubers per plant followed by I_2 (6.58) and I_1 (6.35). Among the sub-treatments V_3 (7.53) produced significantly highest number of tubers per plant over V_4 (5.31) and V_1 (5.84) but tuber number per plant was at par in V_2 (7.40).

Among main-treatments the non-significant result was found on weight of tuber plant^{-1}, maximum tuber weight plant^{-1} was recorded in I_2 (178.36 g) followed by I_3 (172.57 g) and I_1 (144.52 g).

The sub-treatments gave significant result on tuber weight plant^{-1}, V_2 (185.91 g) had significantly highest weight of tuber plant^{-1} over V_4 (128.38 g) but at par with V_3 (170.99 g) and V_1 (175.31 g).

The main-treatments gave significant results on tuber yield, among the treatments I_3 (14.52 t ha^{-1}) yielded highest tuber yield over I_1 (11.56 t ha^{-1}) but was at par with I_2 (14.27 t ha^{-1}). Treatment I_3 (25.61%) and I_2 (23.44%) produced more tuber respectively as compared to I_1.

Significant result was found on tuber yield in sub-treatments, V_2 (15.56 t ha^{-1}) produced significantly highest tuber over V_4 (10.27 t ha^{-1}) but tuber yield was at par with V_3 (13.68 t ha^{-1}) and V_1 (14.19 t ha^{-1}). Among the varieties V_2, V_1 and V_3 recorded 52.48%, 38.17% and 33.20% yield advantage respectively over V_4.

Previous studies showed that limited soil water availability at different stages of growth results in earlier crop maturity (Karafyllidis et al., 1996), tuber yield, the number of tuber plant^{-1}, and tuber size and quality (MacKerron and Jefferies, 1988; Ojala et al., 1990; Lynch et al., 1995; Karafyllidis et al., 1996; Dalla Costa et al., 1997; Yuan et al., 2003). Although in present investigation, a non-significant result in number of tuber plant^{-1} and in weight of tubers plant^{-1} for irrigations treatments but the lesser number of tuber plant^{-1} and weight

Table 4: Effect of irrigations and varietal treatments on yield attributes of potato

Treatments	No. of tubers plant^{-1}	Weight of tuber plant^{-1} (g)	Tuber yield (t ha^{-1})
Main treatments (Irrigation)			
Furrow (I_1)	6.35	144.52	11.56
Micro-sprinkler (I_2)	6.58	178.36	14.27
Gravity-fed Drip (I_3)	6.63	172.57	14.52
SEm±	0.18	7.98	0.55
CD (p=0.05)	NS	NS	2.15
Sub-treatments (Variety)			
Kufri Jyoti (V_1)	5.84	175.31	14.19
Kufri Megha (V_2)	7.40	185.91	15.66
Kufri Giriraj (V_3)	7.53	170.99	13.68
Kufri Giridhari (V_4)	5.31	128.38	10.27
SEm±	0.37	12.63	0.87
CD (p=0.05)	1.11	35.74	2.60

of tubers plant^{-1} were produced by furrow irrigation (I_1), as compared to gravity-fed drip irrigation (I_3) and micro-sprinkler irrigation (I_2), due to the difference in the frequency of irrigation and the non-significant result may be due to the early shower during crop growth period. In irrigations treatments numbers of tubers per plant had non-significant results irrigation, all the treatments produced statistically similar number of tubers plant^{-1} in different irrigation methods. Number of tubers plant^{-1} and weight of tuber plant^{-1} was significantly varies with the varieties due to the adoption, growth habit, temperature and soil type of the variety in the specific region. Similar result was found by Walworth and Carling (2002) that the number of tubers plant^{-1} could be attributed to the cultivars differences as well as other environmental conditions such as soil type and temperature.

3.3. Water use efficiency

Water use efficiency under different irrigation methods were calculated at the time of harvest by dividing yield with the total amount water used.

Significant result was recorded among the main-treatments on field water use efficiency; significantly maximum field water efficiency was recorded for I_3 (20.63 kg ha^{-1} mm^{-1}) as compared to I_1 (14.66 kg ha^{-1} mm^{-1}) but at par with I_2 (18.78 kg ha^{-1} mm^{-1}). Among the irrigation treatments I_3 and I_2 calculated 40.72% and 28.10% WUE advantage respectively over I_1.

Among the sub-treatments significantly maximum field water use efficiency was recorded for V_2 (21.02 kg ha^{-1}mm^{-1}) over, V_4 (13.75 kg ha^{-1} mm^{-1}) but at par with V_1 (19.05 kg ha^{-1}mm^{-1}) and V_3 (18.25 kg ha^{-1} mm^{-1}). In case varieties highest WUE advantage of 52.87% in V_2, 38.55% in V_1 and 32.73% in V_3 over, V_4 (Table 5).

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

Treatments	Field water use efficiency (kg ha^{-1} mm^{-1})
Main treatments (Irrigation)	
Furrow (I_1)	14.66
Micro-sprinkler (I_2)	18.78
Gravityfed-drip (I_3)	20.63
SEm±	0.73
C.D.(p=0.05)	2.85
Sub-treatments (Variety)	
Kufri Jyoti (V_1)	19.05
Kufri Megha (V_2)	21.02
Kufri Giriraj (V_3)	18.25
Kufri Giridhari(V_4)	13.75
SEm±	1.17
CD (p=0.05)	3.48

Water use-efficiency was found significantly higher in I_3 (20.63 kg ha^{-1} mm^{-1}) and I_2 (18.78 kg ha^{-1} mm^{-1}), over, I_1 (14.66 kg ha^{-1} mm^{-1}), because the roots of potato are relatively shallow and concentrated within the raised bed, furrow irrigation often infiltrates under the root zone, while the topsoil of the raised bed is still dry. As such, water use efficiency is very low in case of furrow irrigation as compared gravity-fed drip and micro-sprinkler irrigation (Wang et al., 2006; Erdem et al., 2006).

It was showed that irrigation given at less depletion of available soil moisture resulted in increased yield of tubers, better quality produce, water use efficiency, B:C ratio and saved the precious resource (water) (Bisht et al., 2012). Under varietal treatments significantly highest WUE found in V_2 (21.02 kg ha^{-1} mm^{-1}) along with V_1 (19.05 kg ha^{-1} mm^{-1}) and V_3 (18.75 kg ha^{-1} mm^{-1}) due to the higher yield advantage of the varieties as compared to V_4.

3.4. Economic analysis

The price of the potato was assumed as INR 15 kg^{-1} and the price of the different used materials in the research were assumed as per the local market price for potato production. From the prevailing and assumed market price, the gross return, net return and BCR were calculated and presented in the table below.

Significant results was found on gross return in main treatments, I_3 (INR 2,17,796.75 ha^{-1}) had recorded significantly highest gross return over I_1 (INR 1,73,411.25 ha^{-1}) but at par with I_2 (INR 2,14,010.00 ha^{-1}). In case of net return I_3 (INR 1,21,707.33 ha^{-1}) recorded significantly highest net return over, I_1 (INR 79,748 ha^{-1}) but at par with I_2 (INR 1,21,410.00 ha^{-1}). BCR also showed significant difference among the main-treatments, I_2 (2.31) had significantly highest BCR over I_1 (1.85) but at par with I_3 (2.27).

Table 6: Effect of different irrigations and varieties on economic analysis

Treatments	Economic analysis		
Main treatments (Irrigation)	Gross return (INR ha^{-1})	Net return (INR ha^{-1})	BCR
Furrow (I_1)	173411.25	79748.25	1.85
Micro-sprinkler (I_2)	214010.00	121410.00	2.31
Gravityfed-drip (I_3)	217796.75	121707.33	2.27
SEm±	8232.44	8230.86	0.09
CD (*p*=0.05)	32314.50	32308.30	0.35
Sub-treatments (Variety)			
Kufri Jyoti (V_1)	212880.00	118759.00	2.26
Kufri Megha (V_2)	234849.00	140727.67	2.49
Kufri Giriraj (V_3)	205188.33	111081.78	2.18
Kufri Giridhari(V_4)	154040.00	59919.00	1.64
SEm±	13113.41	13112.79	0.14
CD (*p*=0.05)	38957.50	39955.65	0.41

Significant result was found on gross return, net return and BCR in irrigation treatments, I_3 and I_2 over I_1. In case of gross return, net return and BCR in the varietal-treatments showed significant result on V_2, over, V_4 but at par with V_1 and V_3. The highest net return, gross return, in case of I_3 followed by I_2 because of the highest yield in the treatments, similarly, highest return among the varietal found in V_2 followed by V_1 and V_3. This result was supported by the Narayanan et al. (1994); Sivanappan (1996); Asokaraja (1998); Swarajyalakshmi et al. (2005); Singandupe et al. (2007).

4. Conclusion

Gravity-fed drip irrigation (I_3) and micro-sprinkler irrigation (I_2) are the suitable irrigation techniques for higher yield, WUE and better economy. Among the varieties Kufri Megha (V_2), Kufri Jyoti (V_1) and Kufri Giriraj (V_3) are the suitable varieties for potato cultivation in mid altitude of Meghalaya during the *rabi* season.

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