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Water use Efficiency and Economic Feasibility of Drip Irrigation for Watermelon (*Citrullus lunatus*)

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ABSTRACT

The field experiment was conducted during 2014 and 2015 to assess the water use efficiencies and economics of various drip irrigation systems like surface drip irrigation with mulching, surface drip irrigation without mulching and subsurface drip irrigation with each system having three sub treatment, viz. 80 100 and 120 per cent ET using drip irrigation The water use efficiency (WUE) varied from season to season. For first season (WUE) varied from 18.71 kg/m^3 (80 per cent ET) of surface drip irrigation with mulching (T_1I_1) to 8.10 kg/m^3 (120 per cent ET) of subsurface drip irrigation (T_3I_3) and same trend followed in the second seasons. The highest B: C ratio was found in 80 per cent ET (5.21) of surface drip irrigation with mulching (T_1I_1) and the lowest B: C ratio was found in 120 per cent ET (4.26) with subsurface drip irrigation (T_3I_3) and same trend followed in second season. In both season highest yield was recorded in the 80 per cent ET of surface drip irrigation with mulching than the other treatments.

Key words: *Watermelon, Irrigation, Efficiency, Economics.*

INTRODUCTION

Micro irrigation is a relatively new method, which was developed all over the world towards the later part of the last century. This system has gained wide popularity in areas of acute water scarcity and in areas where horticultural and commercial crops are grown. During the year 1991, micro irrigation was being practiced in as many as 35 countries in the world, out of which India ranked seventh in terms of coverage of area. The other countries, which have brought substantial area under drip irrigation, include USA, Spain, Australia, South Africa, Israel and Italy. The area covered under drip irrigation is highest in Maharashtra followed by Andhra Pradesh and Karnataka[1].

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Subsurface drip irrigation is a low-pressure, high efficiency irrigation system that uses buried drip tubes or drip tape to meet crop water needs. These technologies have been a part of irrigated agriculture since the 1960s; with the technology advancing rapidly in the last three decades. A subsurface system is flexible and can provide frequent light irrigations. This is especially suitable for arid, semi-arid, hot, and windy areas with limited water supply, especially on sandy type soils. Since the water is applied below the soil surface, the effect of surface irrigation characteristics, such as crusting, saturated conditions of ponding water, and potential surface runoff (including soil erosion) are eliminated when using subsurface irrigation. With an appropriately sized and well-maintained system, water application is highly uniform and efficient. Wetting occurs around the tube and water typically moves out in all directions[4].

Water plays an important role in crop production. Irrigation water is often limited and therefore the techniques which help to conserve water in the field are needed. Cultivation with surface mulching is a recommended practice for moisture conservation in arid and semiarid regions.

Over the past decade the use of plastic mulch in agriculture has emerged as a practice closely related to agricultural development in many developed countries. The agricultural and horticultural development in U. S. A., Western Europe, Israel and Japan has been made possible through extensive utilization of plastics. The cultivation of high value crops using methods like drip irrigation, green house plastic much *etc*., can give large income to small farmers.

MATERIALS AND METHODS

The experiment was conducted during February 2014 to May 2014 and November 2014 to February 2015 at Main Agricultural Research Station, UAS Raichur 16˚15' N latitude and 77˚20' E longitude and is at an elevation of 389 m above mean sea level (MSL). The soil was clay loam in texture and had pH of 7.33.

There were three irrigation sub treatments *i.e.* 80, 100 and 120 percent ET in drip irrigation and there were three Main irrigation treatments *i.e.* Surface drip irrigation with mulching, Surface drip irrigation without mulching and Subsurface drip irrigation, taken for the studies which were laid out in split plot design with four replications. Seedlings of Watermelon (Suger Queen) were transplanted at spacing of 2 m X 1 m The seedlings were transplanted in 36 beds of 10 m x 1 m (12 beds were drip with mulching, 12 beds were drip without mulching and 12 beds were subsurface drip irrigation). One lateral of 16 mm diameter was used for each bed with a inline dripper at 90 distance and discharge of 4 lh^{-1}. Irrigation was provided daily after calculating water requirement based on past 24 hours of pan evaporation

Details of calculation needed,

The peak water requirement was calculated by

Q = A x B x C/E Eqn. 1

Where is, Q= Quantity of water required (mm/ day)

A= Daily evapotranspiration (mm)

B= Canopy factor

C= Crop co-efficient

E= Efficiency of drip irrigation system

Duration of irrigation (DI) was calculated by DI (Hours),

DI= Dripper discharge/ (Dripper spacing X Inline spacing). Eqn. 2

The water application efficiency of drip irrigation was calculated by

E_a = (e x q_{min} x T/V) x 100, Eqn. 3 where is, Ea = Application efficiency (%),

e = Total numbers of emitters q_{min} is minimum emitter flow rate (lph),

T = total irrigation time (hr) and total volume of water applied (L)

The water use efficiency of drip irrigation was calculated by

E_u =Y/WR, Eqn.4

where is E_u = Water use efficiency (kg/m^3),

Y = Crop yield (kg)

WR = Total amount of water used in the field (m^3).

This equation was given by Nakayama and Bucks[3].

Amount of irrigation water applied to various treatments were based on daily pan evaporation readings. The irrigation treatments were imposed once the seedlings were established and the total water requirements for Watermelon were obtained by adding up all the depth of water applied for each treatment.

Economics of drip irrigation method was worked out to compute the net returns and benefit-cost ratio. For this purpose, the life period of polyvinyl chloride (PVC) items was considered as 10 years[5] and that of the submersible pump set was taken as 15 years[6]. One ha area, under each treatment was considered for comparison. The fixed cost, operation cost and total cost were worked out. Fixed cost consisted of interest on initial cost and depreciation on the system. The interest calculated on the capital was at the rate of 12 percent per annum as per the prevailing bank rates. The depreciation on the system was worked out as follows.

It was calculated by D= I – S/L, Eqn.5

Where is, D= Depreciation per annum (Rs),

I= Initial cost of system (Rs),

S= Salvage value (10 % of initial cost) and

L = Economic life period.

Operating cost is the amount which is actually paid by the cultivator in cash throughout the crop period for carrying various agricultural operations. Total operational cost of the system is the operating cost plus interest on operational cost at the rate of 12 percent.

RESULTS AND DISCUSSION

Water requirement of Watermelon crop

The first irrigation was applied up to field capacity to all the plots of different irrigation treatments. Subsequently, the irrigation water was delivered through drip irrigation as per treatments and depth of irrigation was calculated. The amount of water applied per month for different levels of drip irrigation in first season is (February 2014 to May 2014) presented in Table 1. For drip irrigation at 80 per cent ET, the monthly water requirement varied from 51.42 mm in February to 149.69 mm in April. Similarly, the amount of water required for 100 and 120 per cent ET varies from 64.28 mm in February to 187.12 mm in April and from 77.13 mm in February to 224.54 mm in April respectively.

Similarly the amount of water applied per month for different levels of drip irrigation in second season is (November 2014 to February 2015) presented in Table 1. For drip irrigation at 80 per cent ET, the monthly water requirement varied from 22 mm in November to 81.67 mm in January. Similarly, the amount of water required for 100 and 120 per cent ET varies from 27.5 mm in November to 102.08 mm in January and from 33 mm in November to 122.5 mm in January respectively.

Irrigation capacity (duty) and delta

Duty is the quantity of water applied to during crop period and Delta is the depth of irrigation (expressed in cm) required during the crop period. Duty and Delta of water for different treatments is presented in Table 2 that with increase in the level of irrigation the amount of water applied also showed an increasing trend; where as the irrigation capacity was found on a decreasing pattern. It was also observed that, the irrigation capacity was lowest in 120 per cent ET for both the seasons. The highest irrigation capacity was obtained for the treatment water application at 80 per cent ET for both the seasons. It is observed from the Table that delta was highest in 120 per cent ET for both the seasons and lowest in 80 per cent ET for both the seasons and it was highest for water application at 120 per cent ET.

Irrigation efficiencies

The application efficiency for different treatments are given in Table.3. It is observed that application efficiency ranged from 94.16 (80 per cent ET) to 93.54 (120 per cent ET) for drip treatments. This shows that the application efficiencies were higher in the drip irrigation treatments. The data is presented in Table 3 indicated that the distribution efficiency ranged from 95.89 (80 per cent ET) to 94.07 (120 per cent ET) for drip irrigation treatments. The Application and distribution efficiency of drip irrigation was found more than 90% for all the drip irrigation treatments of both seasons. The water use efficiency for watermelon as influenced by irrigation methods and levels of drip irrigation are presented in Table 3. The water use efficiency varied season to season. For first season WUE varied from 18.71 kg/m^3 (80 per cent ET) in surface drip irrigation with mulching (T_1I_1) to 8.10 kg/m^3 (120 per cent ET) of subsurface drip irrigation (T_3I_3) and in the second season WUE varied from 31.61 kg/m^3 (80 per cent ET) in surface drip irrigation with mulching (T_1I_1) to 13.58 kg/m^3 (120 per cent ET) in subsurface drip irrigation (T_3I_3).

The application and distribution efficiencies were higher in all drip irrigation treatment. These findings are in agreement with earlier findings of Nakayama and Bucks[3]. The higher application efficiency in drip irrigation system is due to the fact that, in drip irrigation we apply water as required by plant exactly and percolation losses below the crop root zone and the surface run off losses are very less, which results in more efficient application of water.

Economics

The net returns and benefit-cost ratio for different drip irrigation systems and different drip irrigation levels of both seasons are presented in Table 4. It is seen from the results of first season among all the drip irrigation treatments the highest net return of Rs 5, 97,194.92 was obtained from at 80 per cent ET of drip irrigation with mulching (T_1I_1) and the lowest net return of Rs 3,7,1855.27 ha^{-1} was obtained in 120 per cent ET of irrigation through subsurface drip irrigation (T_3T_3) and closely followed by 120 percent ET of surface drip irrigation without mulching, T_2I_3 (3,79,205.27 ha^{-1}). Same Trend followed in second season among all the drip irrigation treatments are the highest net return of Rs 5,92,569.92 ha^{-1} was obtained in the plots of 80 per cent ET of drip irrigation with mulching (T_1I_1) and the lowest net return of Rs 3,62,980.27 ha^{-1} was obtained in 120 per cent ET of irrigation through subsurface drip irrigation (T_3T_3) and closely followed by 120 percent ET of surface drip irrigation without mulching, T_2I_3 (3,95,355.27 ha^{-1}).It is also seen in first season from the Table 4 that among all the drip irrigation treatments the lowest benefit: cost ratio of 4.26 was obtained in 120 percent ET of subsurface drip irrigation and the highest benefit-cost ratio was found in 80 per cent ET (5.21) of drip irrigation with mulching and also same trend followed in second season

The initial cost of installing the drip irrigation system for vegetable crops is high but over a period of time the cost could be recovered and the benefits derived would be higher than furrow irrigation. Even during the first year itself the drip irrigation system at 100 per cent ET and 80 per cent ET level showed maximum net returns as compared to other drip irrigation treatments and furrow irrigation. The net returns in case of 80 per cent ET level was more by 57.2 per cent as compared with furrow irrigation. Similar trend was also exhibited in terms of benefit: cost ratio which was highest (5.96) in case of 80 per cent ET treatment. The results fall in line with the findings of Manjunath *et al*[2].

Table 1: Monthly amount of water applied to Watermelon under different levels of drip Irrigation

Months	Amount of water applied through drip irrigation at different irrigation levels, mm (Summer) During February 2014 to May 2014			Months	Amount water applied through drip irrigation at different irrigation levels, mm (Winter) During November 2014 to February 2015		
	I_1 (80% ET)	I_2 (100% ET)	I_3 (120% ET)		I_1 (80% ET)	I_2 (100% ET)	I_3 (120% ET)
30h January	8.00	8.00	8.00	6th November	8.00	8.00	8.00
February	51.42	64.28	77.13	November	22	27.5	33
March	148.84	186.04	223.25	December	74.32	92.9	111.48
April	149.69	187.12	224.54	January	81.67	102.08	122.5
May*	22.57	28.21	33.85	February**	37.73	47.17	56.6
Total	380.52	473.65	566.77	Total	223.72	277.65	331.58
% saving water over T3	32.9	16.4	00.00	% saving water over T3	32.5	16.3	0.00

* The irrigation Ends 6th May
** The irrigation Ends 10th February

Table 2: Irrigation capacity (duty) of 1m^3 of water and delta of water for different treatments for the crop period during the period of 2014 and 2015

	During February 2014 to May 2014 (Summer)				During November 2014 to February 2015 (Winter)			
Treatment	Water applied in (litre plot^{-1})	Water applied in (m^3 ha^{-1})	Irrigation capacity (ha m^{-3})	Delta (cm)	Water applied in (litre plot^{-1})	Water applied in (m^3 ha^{-1})	Irrigation capacity (ha m^{-3})	Delta (cm)
$T_1 I_1$	3805.2	3805.2	2.6 x10^{-4}	38.05	2237.2	2237.2	4.4 x10^{-4}	22.37
$T_1 I_2$	4736.5	4736.5	2.1 x10^{-4}	47.36	2776.5	2776.5	3.6 x10^{-4}	27.76
$T_1 I_3$	5667.8	5667.8	1.7 x10^{-4}	56.67	3315.8	3315.8	3.0 x10^{-4}	33.15
$T_2 I_1$	3805.2	3805.2	2.6 x10^{-4}	38.05	2237.2	2237.2	4.4 x10^{-4}	22.37
$T_2 I_2$	4736.5	4736.5	2.1 x10^{-4}	47.36	2776.5	2776.5	3.6 x10^{-4}	27.76
$T_2 I_3$	5667.8	5667.8	1.7 x10^{-4}	56.67	3315.8	3315.8	3.0 x10^{-4}	33.15
$T_3 I_1$	3805.2	3805.2	2.6 x10^{-4}	38.05	2237.2	2237.2	4.4 x10^{-4}	22.37
$T_3 I_2$	4736.5	4736.5	2.1 x10^{-4}	47.36	2776.5	2776.5	3.6 x10^{-4}	27.76
$T_3 I_3$	5667.8	5667.8	1.7x10^{-4}	56.67	3315.8	3315.8	3.0 x10^{-4}	33.15

Main Treatments: T_1- Surface drip irrigation with mulching; T_2- Surface drip irrigation without mulch; T_3- Subsurface drip irrigation

Sub Treatments: I_1- 80 per cent ET; I_2- 100 per cent ET; I_3- 120 per cent ET

Table 3: Effect of irrigation methods and different levels of irrigation on irrigation efficiencies during the period of 2014 and 2015

	During February 2014 to May 2014 (Summer)			During November 2014 to February 2015 (Winter)		
Treatments	Application efficiency (%)	Distribution efficiency (%)	Field water use efficiency (kg/m^3)	Application efficiency (%)	Distribution efficiency (%)	Field water use efficiency (kg/m^3)
$T_1 I_1$	94.16	95.89	18.71	94.16	95.89	31.61
$T_1 I_2$	93.76	94.68	13.78	93.76	94.68	23.23
$T_1 I_3$	93.54	94.07	10.72	93.54	94.07	18.01
$T_2 I_1$	94.16	95.89	12.69	94.16	95.89	21.35
$T_2 I_2$	93.76	94.68	10.92	93.76	94.68	18.24
$T_2 I_3$	93.54	94.07	8.25	93.54	94.07	13.78
$T_3 I_1$	94.16	95.89	13.94	94.16	95.89	23.25
$T_3 I_2$	93.76	94.68	10.37	93.76	94.68	17.56
$T_3 I_3$	93.54	94.07	8.10	93.54	94.07	13.58

Table 4: Surface and Subsurface drip irrigation levels in Watermelon crop during the period of 2014 and 2015

	During February 2014 to May 2014					During November 2014 to February 2015				
Treatments	Crop yield t/ha	Total returns Rs ha^{-1}	Total cost of cultivation Rs ha^{-1}	Net returns Rs ha^{-1}	Benefit cost ratio	Crop yield t/ha	Total returns Rs ha^{-1}	Total cost of cultivation Rs ha^{-1}	Net returns Rs ha^{-1}	Benefit cost ratio
$T_1 I_1$	71.18	7,11,800	1,14,605.08	5,97,194.92	5.21	70.72	7,07,175	1,14,605.08	5,92,569.92	5.17
$T_1 I_2$	65.28	6,52,800	1,14,605.08	5,38,194.92	4.70	64.50	6,44,975	1,14,605.08	5,30,369.92	4.63
$T_1 I_3$	60.78	6,07,800	1,14,605.08	4,93,194.92	4.30	59.71	5,97,050	1,14,605.08	4,82,444.92	4.21
$T_2 I_1$	48.28	4,82,800	88,144.73	3,94,655.27	4.48	47.76	4,77,575	88,144.73	3,89,430.27	4.42
$T_2 I_2$	51.73	5,17,325	8,8144.73	4,29,180.27	4.87	50.64	5,06,425	88,144.73	4,18,280.27	4.75
$T_2 I_3$	46.74	4,67,350	88,144.73	3,79,205.27	4.30	45.70	4,56,975	88,144.73	3,68,830.27	4.18
$T_3 I_1$	53.03	5,30,300	87,244.73	4,43,055.27	5.08	52.03	5,20,250	87,244.73	4,33,005.27	4.96
$T_3 I_2$	49.13	4,91,275	87,244.73	4,04,030.27	4.63	48.76	4,87,600	87,244.73	4,00,355.27	4.59
$T_3 I_3$	45.91	4,59,100	87,244.73	3,7,1855.27	4.26	45.02	4,50,225	87,244.73	3,62,980.27	4.16

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