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Mallikarjun Reddy
Assistant Professor, Department of Agricultural Engineering, AC, Kalaburgi, Karnataka, India

Ambrish Ganachari
Assistant Professor, Department of Agricultural Engineering, AC, Kalaburgi, Karnataka, India

Krishna S Maraddi
Assistant Librarian, College of Agriculture Kalaburgi, Karnataka, India

AS Police Patil
Assistant Professor, Department of Agronomy, Kalaburgi, Karnataka, India

Corresponding Author:
Mallikarjun Reddy
Assistant Professor, Department of Agricultural Engineering, AC, Kalaburgi, Karnataka, India

Growth of watermelon under surface and subsurface drip irrigation system in semi-arid region

Mallikarjun Reddy, Ambrish Ganachari, Krishna S Maraddi and AS Police Patil

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Abstract
The field experiment was conducted during 2014 and 2015 to assess the water saving, yield parameter, water use efficiency 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 above parameters are varied from season to season. For first season yield varied from 71.18 t/ha (80 per cent ET) of surface drip irrigation with mulching to 45.91 t/ha (120 per center) of subsurface drip irrigation and same trend followed in the second seasons. For first season (WUE) varied from 18.71 kg/m^3 (80 per cent ET) of surface drip irrigation with mulching to 8.10 kg/m^3 (120 per cent) of subsurface drip irrigation 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 and the lowest B: C ratio was found in 120 per cent ET (4.26) with subsurface drip irrigation and same trend followed in second season. The water saved in drip irrigation over 120% ET was found to be 32.90% and 16.5% for 80% and 100% ET respectively in first season and same trend followed in second season.

Keywords: Watermelon under, subsurface drip irrigation

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 (Mallikarjun Reddy, 2013) [6].
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 (Reich, 2002) [9].
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

During February 2014 to May 2014 and November 2014 to February 2015, the experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences (UAS), Raichur-India. The site was located at 16˚15' N latitude, 77˚20' E longitude and 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 (80, 100 and 120%of ET in drip irrigation) and three main irrigation treatments (Surface drip irrigation with mulching, Surface drip irrigation without mulching, and subsurface drip irrigation), in a split plot design with four replications. Seedlings of watermelon (var. 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 an inline dripper at 90 cm distance and discharge of 4 lph. Irrigation was provided daily after calculating water requirement based on past 24 hours of pan evaporation.

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.

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

Watermelon yield

Table 2 Presents watermelon yield (tons per hectare) for mulch, without mulch and subsurface treatment of different irrigation levels during summer and winter seasons. During summer season (first season), the main plot with mulch gave maximum yield (65.75 tons) followed by subsurface (49.36 tons). The treatment without mulch recorded minimum yield (48.92 tons). Among the different irrigation levels, the plants receiving water at 80% ET gave maximum yield (57.50 tons) followed by 100% ET (55.38 tons). The lowest yield was noticed in 120% ET treatment (51.14 tons).

Table 2: Effects of different treatments on yield (t ha^{-1}) of watermelon

Treatment	During February 2014 to May 2014 (Summer)				During November 2014 to February 2015 (Winter)			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
T_1	71.18	65.28	60.78	65.75	70.72	64.50	59.71	64.97
T_2	48.28	51.73	46.74	48.92	47.76	50.64	45.70	48.03
T_3	53.03	49.13	45.91	49.36	52.03	48.76	45.02	48.60
Mean	57.50	55.38	51.14		56.83	54.63	50.14	

	SEM ± (Summer)	CD at 5% (Summer)	SEM ± (Winter)	CD at 5% (Winter)
Main treatment	2.250	7.787	1.974	6.831
Sub treatment	0.535	1.591	0.667	1.982
I at same T	0.927	2.755	1.156	3.434
T at the same or different I	2.492	7.404	2.383	7.080

Main treatments: Sub treatments
T_1: Mulch condition I_1: Irrigation at 80% ET using drip irrigation
T_2: Without Mulch condition I_2: Irrigation at 100% ET using drip irrigation
T_3: Subsurface drip irrigation I_3: Irrigation at 120% ET using drip irrigation

The interaction effects were significant. The treatment mulch with 80% ET recorded significantly maximum yield (71.18 tons) followed by 100% ET with mulch (65.28 tons). The significantly minimum yield was noticed in subsurface treatment of 120% ET (45.91 tons).

Similar trends were followed in winter season (second season) as shown in Table 2. The main plot with mulch recorded the maximum yield (64.97 t) followed by subsurface treatment (48.60 t). The treatment without mulch recorded the minimum yield (48.03 t). Among the different irrigation levels, the plants receiving water at 80% ET recorded maximum yield (56.83 t) followed by 100% ET (54.63 t). The lowest yield was noticed in 120% ET treatment (50.14 t).

The interaction effects were significant. The treatment mulch with 80% ET recorded the maximum yield (70.72 t) followed by 100% ET with mulch (64.50 t) which indicated significant differences with mulch and 120% ET (59.71 t). The minimum yield was noticed in subsurface treatment of 120% ET (45.02 t). Combination of mulch with drip irrigation in different irrigation levels recorded the maximum yield than the subsurface and without mulch with drip irrigation plots. The Table 1 shows that plastic mulch with 80% of irrigation noticed the maximum yield (71.18 t ha^{-1} in summer season) and70.72 t ha^{-1} in winter season). This was due to higher transpiration rate from the broader leaves even though plastic mulch reduces the evaporation from the soil. The present results obtained are in line with the findings of Tiwari *et al.* [7] and Vijay Kumar *et al.* [8].

Average fruit weight

Data pertaining to average fruit weight of both seasons is presented in Table 3. In first season it can be observed that the main plot treatment with mulch has recorded the highest average fruit weight (3.99 kg) followed by subsurface treatment (3.54 kg) and without mulch plot (3.54 kg). In the different levels of irrigation, the plant receiving water at 80% ET showed the highest average fruit weight (3.81 kg), which was on par with 100% ET (3.73 kg). The minimum average fruit weight was found in 120% ET (3.58 kg).

Among the interaction effectd, the treatment with mulch and 80% ET has recorded the highest fruit weight (4.20 kg), which was on par with 100% ET with mulch treatment (3.95 kg). The lowest average fruit weight was recorded in 120% ET of subsurface treatment (3.45 kg).

In second season, Table 3 shows that the main plot treatment with mulch has recorded the highest average fruit weight (3.97 kg) followed by subsurface treatment (3.43 kg) and without mulch plot (3.39 kg). In the different levels of irrigation, the plant receiving water at 80% ET showed the highest average fruit weight (3.69 kg) which was on par with 100% ET (3.63 kg). The minimum average fruit weight was found in 120% ET (3.48 kg).

Among the interaction effects, the treatment mulch with 80% ET has recorded the highest fruit weight (4.15 kg), which was on par with 100% ET with mulch treatment (3.93 kg). The lowest average fruit weight was recorded in 120% ET of subsurface treatment (3.28 kg).

Table 3: Effects of different treatments on average fruit weight (kg)

Treatment	During February 2014 to May 2014 (Summer)				During November 2014 to February 2015 (Winter)			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
T_1	4.20	3.95	3.83	3.99	4.15	3.93	3.83	3.97
T_2	3.53	3.63	3.48	3.54	3.35	3.53	3.30	3.39
T_3	3.70	3.60	3.45	3.58	3.58	3.45	3.28	3.43
Mean	3.81	3.73	3.58		3.69	3.63	3.47	
		SEM ±	CD at 5%		SEM ±		CD at 5%	
Main treatment		0.15	0.53		0.14		0.49	
Sub treatment		0.05	0.15		0.06		0.17	
I at same T		0.09	0.25		0.10		0.29	
T at the same or different I		0.18	0.54		0.18		0.54	

Main treatments: Sub treatments
T_1: Mulch condition I_1: Irrigation at 80% ET using drip irrigation
T_2: Without Mulch condition I_2: Irrigation at 100% ET using drip irrigation
T_3: Subsurface drip irrigation I_3: Irrigation at 120% ET using drip irrigation

Irrigation efficiencies

The application efficiency for different treatments are given in Table.4. 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 4 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 4. 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 (1986). 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.

Table 4: Effect of irrigation methods and different levels of irrigation on irrigation efficiencies during the period of 2014 and 2015

Treatments	During February 2014 to May 2014 (Summer)			During November 2014 to February 2015 (Winter)		
	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 5: Surface and Subsurface drip irrigation levels in Watermelon crop during the period of 2014 and 2015

Treatments	During February 2014 to May 2014					During November 2014 to February 2015				
	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

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 5. 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.* (2001) [7].

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