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Effect of types of micro irrigation and mulching on yield, water productivity, water use efficiency and economics of bhindi

Jose Merin[1], T. Sajitha Rani[1], P. Shalini Pillai[1], V. Jayakrishnakumar[1] and B. Rani[2]

[1]Department of Agronomy, College of Agriculture, Vellayani, Thiruvananthapuram- 695522. [2]Deparment of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, Thiruvananthapuram- 695522.
**E-mail: pmerinpjose@gmail.com*

Abstract

A field experiment was conducted at the Department of Agronomy, College of Agriculture, Vellayani, Kerala, to evaluate the efficacy of micro irrigation and mulching on growth and yield of bhindi in rain shelter. The experiment was carried out in a split plot design with four replications. The treatment consisted of 5 main plot treatments (i_1: Surface drip irrigation, i_2: Rain hose irrigation, i_3: Sub surface drip irrigation at 10 cm, i_4: Sub surface drip irrigation at 15 cm, i_5: Sub surface drip irrigation at 20 cm) and 2 sub plot treatments (m_1: No mulch, m_2: Organic mulch). Dry banana leaves available in the area was used as organic mulch @ 10 t ha^{-1}. Results of the study revealed that types of irrigation had significant influence on yield and yield attributes, water productivity, water use efficiency and economics of bhindi.Sub surface drip irrigation at 10 cm depth recorded the highest fruit yield m^{-2} (2.29 kg). Water productivity and water use efficiency was 45% and 27% higher in sub surface drip irrigation at 10 cm depth than rain hose irrigation. Significantly higher net returns (₹ 5.31 lakhs ha^{-1}) and B: C ratio (2.39) were observed in sub surface drip irrigation at10 cm depth, which was on par with sub surface drip irrigation at 15 cm depth. Based on the findings of the study, sub surface drip irrigation at 10 cm depth along with organic mulching can be recommended for bhindi cultivation for obtaining higher yield, water use efficiency and economics.

Key words: Micro irrigation, mulching, water productivity, water use efficiency, yield

Introduction

Vegetables are an important part of a healthy diet and are regarded as protective foods due to their high vitamin and mineral contents. Although vegetables may not contribute significantly to calorie requirements, they are a vital source of micronutrients. India is the world's second-largest producer of vegetables. However, daily per capita vegetable consumption is 250g per person per day, which is significantly less than the recommended daily requirement of 300g (Motkuri, 2020). The vegetable supply per capita in India is less than what is recommended by World Health Organization. Meeting the vegetable needs of the world's second-largest and fastest-growing Indian population is an enormous challenge that puts significant pressure on natural resource consumption. It needs further increase in production and supply, which is possible through increases in acreage and/or yield rate with the help of technological advancements.

Irrigation is identified as a decisive factor in Indian agriculture due to high variability and inadequacy of rainfall. Inadequate water availability for frequent irrigation is one of the key challenges impeding vegetable production. The sustainable use of water is a priority for agricultural development. Therefore, techniques that improve water use efficiency and reduce the amount of water applied to the field are critical. As a result, gaining a better understanding of micro irrigation systems that make efficient use of water resources would be an effective approach for addressing the problems of the agricultural sector in the country and boosting its growth.

Micro irrigation techniques can be used to improve irrigation efficiency by reducing soil evaporation and drainage losses and by creating and maintaining soil moisture conditions that are favourable to crop growth. Micro irrigation, in conjunction with proper soil and moisture conservation practices such as the application of mulch, would alleviate soil moisture stress.

Micro irrigation is the slow application of water as discrete or continuous strips, tiny streams,or miniature spray on, above, or below the soil by surface drip, sub surface drip, bubbler or micro sprinkler system (Lamm *et al.*, 2006). The required quantity of water is provided to each plant daily at the root zone through a pipe network. Hence, there is little loss of water in the conveyance and distribution system and only a small loss by evaporation from the surface.

Singh *et al.* (2006) classified micro irrigation systems on the basis of their installations in the field *i.e.*, surface method or sub surface method. In the surface method, the drip lateral is laid along with the row of crops on the surface ground and the drippers/ micro-sprinklers/ micro-sprayers are installed as per layout and design. The system has an advantage when short duration crops are grown, *i.e.*, vegetables/ cash crops. It can be rolled back when not required for irrigation activity. Sub surface installations are generally preferred in semi-permanent/ permanent installation, particularly for orchards.

The major advantages of sub surface drip irrigation are the improvement in soil water status for crops, which results in faster maturity of crops, saving of scarce precious water, and improving irrigation efficiency by about 30% over conventional drip irrigation. The weed problem is almost nil, as the surface of the soil remains dry. Heavy textured soils are well suited for sub surface drip irrigation where the applicability of surface drip irrigation is difficult. Soils having a very high-water intake rate and stones in the substratum are not suitable for sub surface drip irrigation.

Rain hose irrigation is a new innovative irrigation technology. It is a low-cost spray irrigation method that can be used instead of a sprinkler system. It is otherwise called 'rain pipe irrigation' and is easy to install and maintain. A rain hose is a flexible hose with a pattern of drip holes. To maintain a consistent flow of water, these drip holes are made using nano punching technology.

Mulching increases infiltration of water, conserves moisture, regulates temperature, suppresses weed growth, decreases evaporation, enhances microbial activity, and also improves soil fertility. Biodegradable mulches are safe to the environment as they are decomposed in the soil at the end of the growing season, leading to a reduction in plastic waste compared to plastic mulch (El-Beltagi *et al.*, 2022).

Judicious usage of irrigation water is inevitable in the present context of climate change and micro irrigation is getting momentum these days. With the diminishing per capita water availability along with increased ground water exploitation, it has become imperative to switch on to water saving irrigation technologies like micro irrigation. Hence, this study was performed to assess the effectiveness of micro irrigation and mulching on growth and yield of bhindi and to work out its economics.

Materials and methods

The field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during the summer season of 2021. The soil of the experimental site was sandy clay loam in texture and moderately acidic in soil reaction. The field experiment was conducted in a split plot design with 4 replications, using the variety Varsha Uphar. The treatment consisted of 5 main plot treatments (i_1: Surface drip irrigation, i_2: Rain hose irrigation, i_3: Sub surface drip irrigation at 10 cm, i_4: Sub surface drip irrigation at 15 cm, i_5: Sub surface drip irrigation at 20 cm) and 2 sub plot treatments (m_1: No mulch, m_2: Organic mulch). Dry banana leaves available in the area was used as organic mulch @ 10t ha^{-1} and they were laid as per the treatment. After thorough field preparation the composite soil samples were drawn from 0-30 cm depth and the physical and chemical properties were analyzed. The pH of the experimental field was 5.7, EC 0.09 dSm^{-} and organic carbon was 1.25%. The N status of the experimental field was medium in available N (270.6 kg ha^{-1}), medium in available P (46.57 kg ha^{-1}), and available K status was medium in range (176 kg ha^{-1}). FYM @ 25 t ha^{-1} were given at the time of land preparation. 98:25:136 kg NPK ha^{-1} was given through fertigation at 3 days interval. Fertilizers were urea (46:0:0) and polyfeed (19:19:19) as N source, mono ammonium phosphate (12:61:0) as P source and potassium nitrate (13:0:45) as K source. Irrigation was given daily. The daily water requirement for fully-grown plants was calculated as under:

V = E p x Kc x Kp x Wp x Sp;

V - Water requirement in litre per day per plant, Ep - Average pan evaporation, Kc - Crop coefficient, Kp - Pan coefficient, Wp - Wetted area, which is shaded due to canopy, Sp - spacing of crops in m^2 (Reddy and Reddy, 2019).

As the roots were too short during the seedling stage manual watering was done for a period of one week to ensure that the roots get enough water to survive. Irrigations were scheduled based on the daily crop water requirement of the crop in Vellayani region of Thiruvananthapuram district in Kerala. The discharge rate of the emitter was 2 Lh^{-1} at a nominal pressure of 1.5 kg cm^{-2}.

For analyzing the growth pattern of crops, four plants were selected randomly from the net plot area from each replication, tagged as observational plant. Data generated from the experiment were subjected to statistical analysis by applying ANOVA for split plot design and significance was tested.

Results and discussion

Yield and yield attributes: The effects of types of micro irrigation and mulching on yield and yield attributes of bhindi are presented in Table 1. The highest number of fruits plant^{-1} was recorded by sub surface drip irrigation at 10 cm (28.00) which was on par with sub surface drip irrigation at 15 cm (27.67) and sub surface drip irrigation at 20 cm (27.60). The lowest number of fruits plant^{-1} was recorded by rain hose irrigation (24.17) which was on par with surface drip irrigation. The highest fruit lengthwas recorded by sub surface drip irrigation at 10 cm (15.53 cm) and the lowest fruit length was observed under rain hose irrigation (13.30 cm). Sub surface drip irrigation at 10 cm depth (i_3) recorded higher fruit yield plant^{-1} (411.19 g) and it was on par with sub surface drip irrigation at 15 cm (387.96 g). The lowest fruit yield plant^{-1} was recorded by rain hose irrigation (299.29 g), which was on par with surface drip irrigation (304.23 g). Total fruit yield m^{-2} was observed to be the highest in sub surface drip irrigation at 10 cm (2.29 kg) and it was on par with sub surface drip irrigation at 15 cm (2.15 kg). The lowest fruit yield m^{-2} was recorded by rain hose irrigation (1.66 kg), which was on par with surface drip irrigation (1.69 kg). Organic mulching recorded significantly higher yield and yield attributes compared to no mulch. Significant interaction was noticed between types of irrigation and mulching on total fruit yield m^{-2}. The treatment sub surface drip irrigation at 10 cm depth with organic mulch (i_3m_2) was observed to be significantly superior (2.33 kg) compared to all other treatment combinations. The lowest value was recorded by rain hose irrigation without mulch (i_2m_1) (1.61 kg), which was on par with surface drip irrigation without mulch (i_1m_1) (1.63 kg).

The highest yield and yield attributes in sub surface drip irrigation at 10 cm depth might be due to the increased number of branches plant^{-1}, which resulted in increased number of fruits thereby producing maximum yield. Though the same amount of water was applied in all types of irrigation, water application through sub surface drip had resulted in the uniform application of water across the field as well as directly to the root zone of the plant, producing an extensive root system and other growth attributes. Yield decreased at 20 cm depth as greater depth of placement of laterals requires a larger volume of water for upward movement up to the soil surface which might have resulted in a decreased availability of water in the effective root zone. Singh and Rajput (2012) reported that the maximum yield was found in okra when the laterals of sub surface drip irrigation were placed at a depth

Table 1. Effect of types of micro irrigation and mulching on yield and yield attributes of bhindi

Treatments	Number of fruits plant^{-1}	Length of fruit (cm)	Fruit yield plant^{-1} (g)	Total fruit yield m^{-2} (kg)
i_1: Surface drip	25.17	13.85	304.23	1.69
i_2: Rain hose	24.17	13.30	299.29	1.66
i_3: Sub surface drip 10 cm	28.00	15.53	411.19	2.29
i_4: Sub surface drip 15 cm	27.67	15.37	387.96	2.15
i_5: Sub surface drip 20 cm	27.60	13.80	343.75	1.91
SE m (±)	0.63	0.04	11.57	0.06
CD (0.05)	2.045	0.132	37.715	0.210
m_1: No mulch	26.13	14.29	342.17	1.90
m_2: Organic mulch	26.93	14.45	356.38	1.98
SE m (±)	0.22	0.03	3.20	0.02
CD (0.05)	0.697	0.101	10.094	0.056
Interaction (I × M)				
i_1m_1	24.33	13.67	287.52	1.63
i_1m_2	26.00	14.03	320.93	1.75
i_2m_1	23.33	13.27	290.92	1.61
i_2m_2	25.00	13.33	307.65	1.71
i_3m_1	28.00	15.37	404.09	2.25
i_3m_2	28.00	15.37	418.28	2.33
i_4m_1	27.00	15.37	375.45	2.08
i_4m_2	28.33	15.37	400.46	2.22
i_5m_1	28.00	13.77	352.87	1.96
i_5m_2	27.33	13.83	334.62	1.86
SE m (±)	0.49	0.07	7.16	0.04
CD (0.05)	NS	NS	22.573	0.125

NS- Non Significant

of 10 cm when compared to surface drip irrigation. Nisha *et al.* (2020) reported that the drip irrigation levels gave higher yield of watermelon than surface irrigation and concluded that the increased yield under drip irrigation system might be due to excellent soil-water-air relationship with higher oxygen concentration in the root zone, higher uptake of nutrients and continuous maintenance of higher soil moisture content to fulfil the evapotranspirational need of the crop. Similar conclusions were made by Vadar *et al.* (2019). Rain hose irrigation has recorded the lowest yield attributes and yield compared to sub surface drip irrigation, as adequate moisture could not be maintained throughout the growing period of the crop.

Significantly higher yield attributes and yield were recorded in organic mulch treatment compared to no mulch. This might probably be due to the higher moisture retention, favourable soil temperature, reduced runoff and evaporation. Decomposition of organic mulch also adds to the nutrient content of the soil and might have increased the crop yield. This is in line with the findings of Bhardwaj (2013), who reported that organic mulch increased the crop yield.

Among the interactions, the treatment combination i_3m_2, *i.e.*, sub surface drip irrigation at 10 cm depth along with organic mulching recorded the highest fruit yield plant^{-1}, and total fruit yield m^{-2} reflecting the suitability of the sub surface drip irrigation at 10 cm depth with organic mulching. The interaction between organic mulch, and sub surface drip irrigation might be due to the fact that both tend to increase soil water storage within the root zone and made more water available to crops. This is in conformity with the findings of Adekalu *et al.* (2008]). Sunilkumar and Jaikumaran (2006) reported that mulched and drip irrigated bhindi crop produced maximum fruit yield ha^{-1}. Similar findings were made by Patel *et al.* (2019) and Bahadur *et al.* (2009) in bhindi.

Water productivity and water use efficiency: Sub surface drip irrigation at 10 cm depth resulted in the highest water productivity (4.49 kg m^{-3}). The lowest water productivity was recorded by rain hose irrigation (3.09 kg m^{-3}), which was on par with surface drip irrigation. Organic mulching recorded significantly higher water productivity compared to no mulch (Fig. 1). Among the interactions sub surface drip irrigation at 10 cm along with organic mulch recorded higher water productivity (4.53 kg m^{-3}) which was on par with i_3m_1 and i_4m_2. The lowest water productivity was recorded by rain hose irrigation without mulch (Table 2).

Table 2. Effect of types of micro irrigation and mulching on water productivity, field water use efficiency and economics of bhindi

Treatments	Water productivity (kg m^{-3})	Field water use efficiency (kg m^{-3})	Net returns (₹ lakhs ha^{-1})	B:C ratio
i_1: Surface drip	3.21	4.79	2.94	1.77
i_2: Rain hose	3.09	4.71	2.99	1.82
i_3: Sub surface drip 10 cm	4.49	6.48	5.31	2.39
i_4: Sub surface drip 15 cm	3.95	6.11	4.80	2.25
i_5: Sub surface drip 20 cm	3.66	5.41	3.81	1.10
SE m (±)	0.06	0.18	0.26	0.07
CD (0.05)	0.179	0.594	0.840	0.219
m_1: No mulch	3.51	5.39	3.81	2.00
m_2: Organic mulch	3.85	5.61	4.13	2.09
SE m (±)	0.06	0.05	0.07	0.02
CD (0.05)	0.192	0.159	0.225	0.060
Interaction (I × M)				
i_1m_1	3.52	4.53	2.57	1.67
i_1m_2	2.91	5.05	3.31	1.86
i_2m_1	2.40	4.58	2.81	1.77
i_2m_2	3.77	4.84	3.18	1.87
i_3m_1	4.44	6.37	5.16	2.35
i_3m_2	4.53	6.59	5.47	2.43
i_4m_1	3.60	5.91	4.52	2.18
i_4m_2	4.30	6.31	5.08	2.33
i_5m_1	3.61	5.56	4.01	2.05
i_5m_2	3.72	5.27	3.61	1.94
SE m (±)	0.14	0.11	0.16	0.04
CD (0.05)	0.430	0.355	0.503	0.133

NS- Non Significant

The field water use efficiency (FWUE) was observed to be the highest in sub surface drip irrigation at 10 cm depth (6.48 kg m^{-3}) and was comparable with sub surface drip irrigation at 15 cm depth. The lowest FWUE was recorded in the plots irrigated using rain hose and it was on par with surface drip irrigation. Between mulch and no mulch, organic mulching recorded a significantly higher FWUE (5.61 kg m^{-3}) than no mulch (Fig. 2). The interaction effect was found to be significantly higher in sub surface drip irrigation at 10 cm along with organic mulch (6.59 kg m^{-3}), and it was on par with sub surface drip irrigation at 10 cm without mulch (i_3m_1) and sub surface drip irrigation at 15 cm along with organic mulch (i_4m_2). Lower FWUE was recorded by surface drip irrigation without mulch (4.53 kg m^{-3}) which was on par with rain hose irrigation without mulch (i_2m_1) and surface drip irrigation with mulch (i_1m_2) (Table 2).

The high water use efficiency and water productivity in sub surface drip irrigation might be due to the application of water

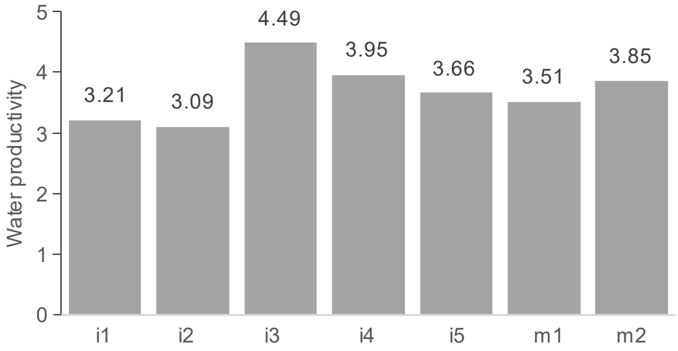

Fig. 1. Effect of types of micro irrigation and mulching on water productivity, kg m^{-3}

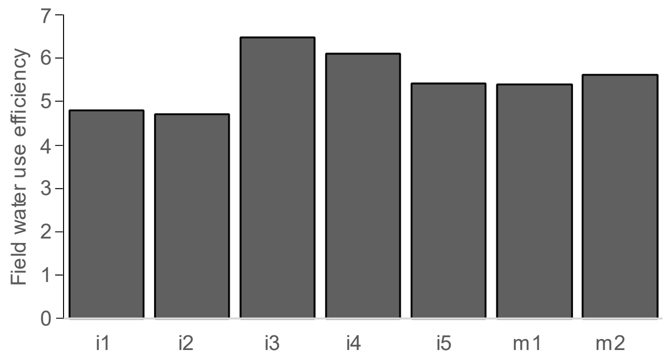

Fig. 2. Effect of types of micro irrigation and mulching on field water use efficiency, kg m^{-3}

directly to the root zone, maintaining favourable root zone moisture conditions and less evaporational loss. Among organic mulch and no mulch, organic mulched treatment recorded higher water productivity. This is in conformity with the findings of Biswas *et al.* (2015), who reported that drip irrigation with mulch has an explicit role in increasing the land and water productivity of tomato. Similar findings were reported by Jha *et al.* (2017), who observed that drip irrigation consistently recorded higher water productivity with more than five folds increase in the case of potato and cauliflower when compared with furrow irrigation.

The water applied through sub surface drip irrigated plots gets utilized efficiently since it is applied directly to the root zone, whereas, most of the water applied to the field in the case of rain hose irrigated plots gets evaporated from the surface. Sub surface drip irrigation creates more suitable conditions in the root zone area for the plant growth and production. This is in conformity with the findings of Douh and Boujelben (2011) in maize. The distribution of soil water content for mulched plots was more uniform than the non- mulched plots (Al- Othman *et al.*, 2020). Application of water and nutrients at an optimum amount to the most active part of the crop root zone, with maximum plant response minimizes the potential of nutrient leaching. The behaviour of water use efficiency with placement depth of laterals followed the same trend as the yield of okra. The reason is that amount of water applied was the same for all the treatments, while only the yield changed.

Economics of cultivation: The economics of cultivation was worked in terms of net returns and benefit-cost ratio. The highest net returns were generated by sub surface drip irrigation at 10 cm depth, which recorded a net return of ₹ 5.31 lakhs ha^{-1} which was on par with sub surface drip irrigation at 15 cm depth (₹ 4.80 lakhs ha^{-1}). Lower monetary returns were obtained from surface drip irrigation (₹ 2.94 lakhs ha^{-1}) and rain hose irrigation compared to sub surface drip irrigation (₹ 2.99 lakhs ha^{-1}). Sub surface drip irrigation at 10 cm depth recorded the highest B: C ratio (2.39) which was on par with sub surface drip irrigation at 15 cm depth (2.25). Sub surface drip irrigation at 20 cm depth recorded the lowest B: C ratio (1.10) (Fig. 3). Between organic mulch and no mulch, organic mulched plots recorded higher net returns and B: C ratio. Among the interaction effects, B: C ratio was as high as 2.43 and net returns of ₹ 5.47 lakhs ha^{-1} were generated from the treatment combination i_3m_2, *i.e.,* sub surface drip irrigation at 10 cm depth with organic mulching, which was on par with sub surface drip irrigation at 15 cm depth with organic mulching (i_4m_2) (Table 2).

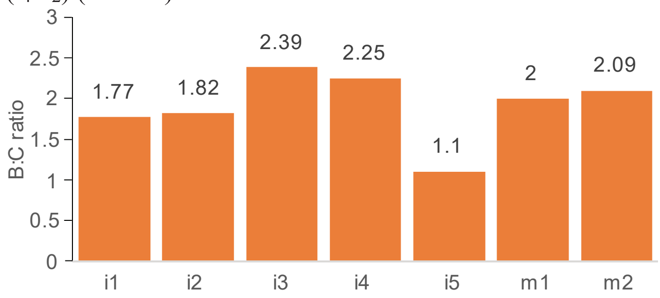

Fig. 3. Effect of types of micro irrigation and mulching on B: C ratio

Lower monetary returns were obtained from surface drip irrigation and rain hose irrigation compared to sub surface drip irrigation, as there was reduction in yield because of the moisture stress experienced by the crop.

Based on the findings of this study, it can be concluded that sub surface drip irrigation at a depth of 10 cm combined with organic mulch (dry banana leaves) @ 10 t ha^{-1} can be recommended for bhindi cultivation for obtaining higher yield, water use efficiency and economics.

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