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Impact of Sensor-based Drip Irrigation System on Soil Temperature, Weed Density and Yield of Ridge Gourd (*Luffa acutangula* L.)

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ABSTRACT: Ridge gourd was the subject of a field experiment at the Experimental Research Plot Soil and Water Engineering, CAE, Raichur, during the *Rabi* seasons of 2021-22 and 2022-23. The purpose of the research was to compare the performance of mulched and non-mulched circumstances while evaluating the effectiveness of an irrigation system based on sensors and evapotranspiration at various irrigation levels. The soil temperatures at depths of 3, 10, and 20 cm were consistently higher in the treatments conducted under mulched conditions. This was seen at three different time points: 8:00 AM, 1:00 PM, and 5:00 PM. The measurements were taken at 30, 60, and 90 days after treatment (DAT) of the crop. The soil temperature exhibited an increase of about 1.42, 1.42, and 1.34ºC when compared to the irrigation system in the absence of mulching, at soil depths of 3, 10, and 20 cm respectively. Positive results from the application of sensor-based irrigation at 100% field capacity under mulching have resulted in a noticeable increase in crop output of roughly 9.40%. Additionally, this strategy has significantly reduced the need for irrigation water. The highest benefit cost ratio was under surface drip irrigation at 100% ET under mulched condition, *i.e.*, 1.90. The sensor-based drip irrigation system under mulched is an economically viable option to be recommended among farmers in arid and semi-arid climate. Although initial setup costs may be higher, the long-term benefits of reduced water usage, increased yields and minimized labour expenses result in substantial cost savings for farmers.

Keywords: Mulch, Irrigation, Sensor, Soil temperature, Yield and B.C ratio.

INTRODUCTION

Ridge gourd [*Luffa acutangula* L.] originated in India and commonly called as Turai. It is an important tropical and sub-tropical cucurbitaceous vegetable, its originated in sub-tropical Asian region including India (Bhat *et al*, 2018). It is grown in both season summer and rainy. The name "Luff" or "Loofah" is an Arabic origin and mention to the spongy characteristic of the mature fruit. It contains a gummy compound called "luffein", which has medicinal importance (Bose and Som 1986). Fruit is diuretic and nutritious. It's fruits are beneficial for those people, who suffer from malaria and other seasonal fever for its easy digestibility and very appetizing quality (Yawalkar, 1985). It is beneficial for icterus patients and cure tetanus. The edible portion of fruit contains, 0.5 g of protein, 1.95 g of fibre content, 0.35 per cent of carbohydrate, 37 mg of carotene, 5.0 mg of vitamin C, 18 mg of calcium and 0.5 mg of Iron for every 100 g (Krishnamoorthy and Ananthan 2017). Seeds of ridge gourd are contains 18 to 25 per cent protein and 18.3 to 24.3 per cent oil.

However, there is a lack of information regarding the yield of ridge gourd cultivated on various irrigation scenarios The application of mulches to soil is believed to have been a common agricultural practise since ancient times. There are two main types of mulches: organic mulches, which are generated from plant and animal components, and inorganic mulches, which are composed of plastic film. The practise of mulching has been found to be advantageous for the development of crops. When mulches are utilised in an appropriate manner, they have the potential to provide all the advantages associated with any type of mulch, with the exception of potentially not contributing to early season soil warming. One of the primary environmental impacts of organic mulches is the decrease in soil temperature (Schmidt and Worthington, 1998). The use of plastic mulch in agriculture has increased dramatically in the last 10 years throughout the world. This increase is due to benefits such as increase in soil temperature, reduced weed pressure, moisture conservation, reduction of certain insect pests, higher crop yields and more efficient use of soil nutrients (Subrahmaniyan and Ngouajio 2012; Bhanukar *et al*., 2015).

The majority of reports shown that increased root-zone temperature is one of the main benefit associated with the use of plastic mulches. Additional studies also show that, depending on the crop species, geographical region, or time of the year, plastic mulches create high zone-temperature conditions that may be deleterious to growth and yield of vegetables (Diaz-Perez and Batal 2002; Ibarra-Jimenez *et al*., 2008; Lamont, 2005).

The increased root-zone temperature is responsible for rapid initial plant growth and high yield of ridge gourd as compared to control. However, there is a lack of information regarding the yield of ridge gourd cultivated on various irrigation scenarios in the North Eastern Dry zone of Karnataka. With this fact in mind, the study was undertaken to investigate the impacts of different irrigation levels on soil temperatures and to assess the growth and yield outcomes of ridge gourd cultivated under mulched and non-mulched condition using a drip irrigation system.

MATERIAL AND METHODS

The experimental studies were carried out at the Experimental Research Plot, which is situated within the Department of Soil and Water Engineering at the College of Agricultural Engineering, University of Agricultural Sciences, Raichur. The specific coordinates of the location are 16°12′8.34″N latitude and 77°19′49.47″E longitude, with an elevation of 394 m above mean sea level (MSL).

The 35 years normal weather data values are summarized as follows; annual maximum and minimum temperature of Raichur is 34.2 and 21.1 ºC, respectively. The station receives an average rainfall of 625.9 mm with 33 rainy days. Average annual evaporation is 5.9 mm day^{-1} with 5.98 km h^{-1} wind speed, 7 hr of sunshine a day and relative humidity of 76.7 and 41.08% in morning and evening, respectively. The weather data for the cropping period of 2021-22 and 2022-23 are depicted in Fig. 1 and 2.

A. Characterization of soil

Soil properties are one of the most important factors that govern the movement of water particles through the vadose zone. The soil profile at the experimental plot was initially analyzed by digging a pit of 0.3 × 0.3 m cross section with about 60 cm depth (Plate 1). No slacking layers were found in the profile that ensured cultivation of ridge gourd crop at the site. Soil samples were collected before sowing of the crop from 0-40 cm depth at 10 cm interval each using core samplers, which were then used for characterization of physico-chemical properties of the soil.

The physico-chemical properties of the soil and the methodologies adopted for the determination are illustrated in Table 1**.** The methodologies are briefly given below

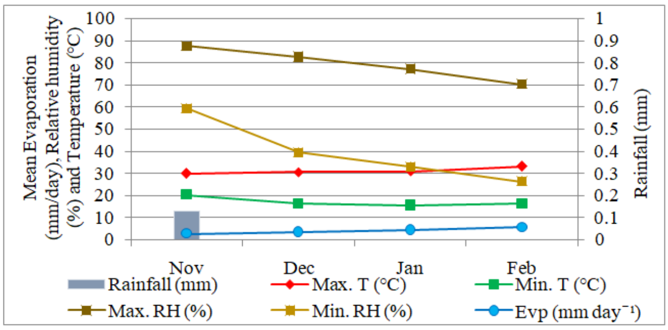

Fig. 1. Mean monthly maximum and minimum temperature, maximum and minimum relative humidity, pan evaporation and rainfall during 2021-22.

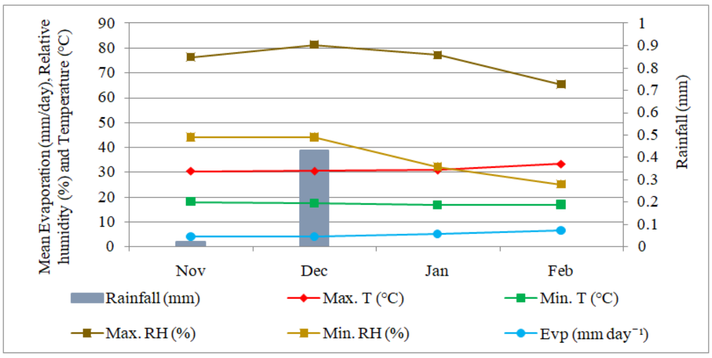

Fig. 2. Mean monthly maximum and minimum temperature, maximum and minimum relative humidity, pan evaporation and rainfall during of 2022-23.

Table 1: Physico-chemical parameters of soil in the experiment field and the methodologies followed.

Sr. No.	Parameters	Methodology/ Instrument	References
1.	Soil texture	International pipette method	Piper (1966)
2.	Bulk density	Core cutter method	Piper (1966)
3.	Field capacity (FC)	Pressure Plate apparatus (0.33 bar)	Richards and Weaver (1964)
4.	Permanent wilting point (PWP)	Pressure Plate apparatus (15.00 bar)	Richards and Weaver (1964)
5.	Maximum water holding capacity (MWHC)	Keen's cup method	Keen and Reckzowaski (1921)
6.	Basic infiltration rate	Double ring infiltration test	Anonymous (2009)
7.	Hydraulic conductivity	Inverse auger hole	Ritzemma (1994)
8.	pH	pH meter	Jackson (1973)
9.	Electrical conductivity	Conductivity bridge	Jackson (1973)
10.	Organic carbon	Wet digestion and titration	Walkley and Black (1934)
11.	Available nitrogen	Kjeldahl method	Kjeldahl (1883)
12.	Available phosphorus	Olsen's method	Olsen *et al*. (1954)
13.	Available potassium	Flame photometer	Hanway and Heidal (1952)

B. Experimental Setup

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. The experiment consisted of eight treatments in each replication and it was replicated thrice as mentioned below.

1. Treatment Details

T_1: SDIS under mulched condition water application at 100% field capacity level

T_2: SDIS under non-mulched condition water application at 100% field capacity level

T_3: SDIS under mulched condition water application at 80% field capacity level

T_4: SDIS under non-mulched condition water application at 80% field capacity level

T_5: Surface drip irrigation under mulched condition water application at 100% ET level

T_6: Surface drip irrigation under non-mulched condition water application at 100% ET level

T_7: Surface drip irrigation under mulched condition water application at 80% ET level

T_8: Surface drip irrigation under non-mulched condition water application at 80% ET level

SDIS: Sensor based drip irrigation system, ET: Evapotranspiration

2. Crop details

Crop: Ridge gourd (*Luffa acutangula*, L.)

Variety: Naga F_1

Spacing: 120×90 cm

Season: *Rabi* 2022 and 2023

Location: Experimental plots, SWE, CAE, Raichur

C. Field observations

The field observations comprised of recording soil temperature, weed density, growth and yield parameters of the crop. The soil samples were collected at pre-scheduled timings for the estimation of available nitrogen, phosphorus and potassium for analysis.

1. Soil temperature. The soil temperature is an important parameter representing the microclimate of the crop root zone. Soil temperature at 3, 10 and 20 cm below the ground in all the replications was recorded at 8:00 AM, 1:00 PM and 5:00 PM with the temperature probe. The measurements were repeated for 30 days interval after sowing irrigation.

2. Weed density. In each treatment, a square section of 1 × 1 m was selected at two ends. The weed population was counted in each plot and after that hand weeding was done at 30, 60 90 and 103 DAS during 2021-22 and 2022-23 and it was expressed as number of weeds per m^{-2}.

3. Fruit yield per plant (kg). All the marketable fruits harvested and weighed during each picking were to talled and recorded as total yield per plant which was expressed in kilogram.

4. Fruit yield per plot (kg). The fruit yield per plot was computed by summing up all the harvested fruits from each treatment and expressed in kilogram.

5. Crop yield (t ha^{-1}). The fruit yield per hectare was worked out based on the fruit weight per net plot and expressed in tons per hectare.

D. Calculation of gross income and benefit cost ratio

The gross income of the crop was calculated from yield and prevailing market price of ridge gourd. Benefit-cost ratio (BCR) indicates the return from the crop under each treatment. It can be calculated by equation (1) (Reddy and Ram 2011). If the BCR obtained is more than one, the project is acceptable.

$$\mathrm{BCR} = \frac{\sum_{t=1}^{n} B_t \, (1+i)^{-t}}{\sum_{t=1}^{n} C_t \, (1+i)^{-t}} \qquad \text{(Eqn. 1)}$$

Where,

B_t= Benefit in i^{th} year;

C_t = Cost in i^{th} year;

I= Discount rate.

t = Number of years.

E. Statistical analysis

The growth, yield and quality parameters of the ridge gourd crop were taken at 30, 60, 90 and 103 DAS and other relevant observations taken periodically during the experiment were analyzed statistically using the split plot design. The significance of each of the results was estimated at 5% level of significance. The calculations were done with the help of "OPSTAT" software.

RESULTS AND DISCUSSION

A. Characterization of soil

The soil in the experiment site belongs to sandy clay texture at 0-40 cm depth. The bulk density of soil at 0-10, 10-20, 20-30 and 30-40 cm depths were 1.50, 1.53, 1.62 and 1.72 g cm^{-3}. Consistent tractor operations prior to crop season might have resulted in more soil compaction in sub soil layers. The field capacity (FC) and permanent wilting point (PWP) at 0-10 cm soil layer were 42.26 and 23.14, at 10-20 cm which were 41 and 22% on volumetric basis. At 20-30 cm soil depth was recorded with 40.86 and 21.84%, whereas at 30-40 cm it was observed to be 40.21 and 21.32%, respectively. The maximum water holding capacity at 0-10, 10-20, 20-30 and 20-40 cm depths were 54.18, 53.26, 52.21 and 51.94%, respectively. The basic infiltration rate of 1.47 cm h^{-1} was recorded. The inverse auger hole experiment showed hydraulic conductivities of 11.31 and 2.72 cm d^{-1} at 0-20 and 20-40 cm soil depths, respectively (Table 2).

The pH of the soil was 7.63 and 7.65 at a depth of 0-10 and 10-20 cm and 7.68 at 20-30 and 30-40 cm. The electrical conductivity was 1.32, 1.37, 1.40 and 1.43 dS m^{-1} in soil depths of 0-10, 10-20, 20-30 and 20-40 cm, respectively. The organic carbon content in soil depths of 0-10, 10-20, 20-30 and 20-40 cm was measured to be 0.68%, 0.65%, 0.63%, and 0.62%, respectively. The available of nitrogen, phosphorus and potassium in the soil at depths of 0-10 cm, 10-20 cm, 20-30 cm, and 30-40 cm were measured and recorded in Table 3. The available of nitrogen, phosphorus and potassium in the soil were recorded as 126.54, 30.84 and 296.73 kg ha^{-1}, respectively, at the topmost layer. In the subsequent layers, the concentrations were found to be 123.24, 27.78 and 278.29 kg ha^{-1} at 10-20 cm depth, 106.47, 15.54, and 253.26 kg ha^{-1} at 20-30 cm depth and 97.74, 10.67 and 296.17 kg ha^{-1} at 30-40 cm depth, respectively.

B. Field observations

Soil temperature. Soil temperature was monitored at 3, 10 and 20 cm depths for 30, 60, 90 and 103 DAS in all the treatments in order to understand the effect of different irrigation scenarios under mulched and non-mulched conditions. The pooled results of soil temperature observations are shown below.

Soil temperature at 30 DAS. The soil temperature at 30 DAS was significantly influenced at 3, 10 and 20 cm depths and different timings in the raised beds of ridge gourd for different treatments which are shown in Table 4. Among all the treatments, irrigation at 80% FC under mulched condition has recorded higher soil temperatures *i.e.*, 29.84, 31.28 and 30.26 at 8:00 AM, 1:00 PM and 5:00 PM followed by irrigation at 80% FC under non-mulched condition and the lowest soil temperature was recorded in the treatment response to irrigation at 100% ET under non-mulched condition. At 8:00 AM, the irrigation at 100% ET under non-mulched condition recorded the lowest temperatures, *i.e.*, 23.60, 24.80 and 26 ºC at 3, 10 and 20 cm depths, respectively. The treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 and T_7 resulted in an increase of soil temperature ranges from 1.52-1.18, 1.60-1.15 and 1.84-1.15 ºC at 3, 10, 20 cm depth of soil layers respectively, when compared to corresponding depth in the treatments irrigation under non-mulched condition *i.e.*, T_2, T_4, T_6 and T_8. With increase in depth, the soil temperature increased in all the treatments and the maximum variation of 2.72 ºC was observed between the top and 20 cm depths in the treatment response to irrigation at 100% FC under non-mulched condition and followed by the irrigation at 80% ET under non-mulched condition (2.58 ºC) and minimum variation was observed in the treatment response to irrigation at 80% FC under mulched condition (2.18 ºC). This might be due to high transmission of incoming shortwave solar radiation through polythene mulch and also the condensed water droplets under surface of mulch which blocked the outgoing long wave infrared radiation. Due to this, polythene mulch retained more heat and which is responsible for higher soil temperature under polythene mulch. According to Ham *et al.* (1993) the white on black plastic mulch absorbs little solar radiation but transmits 100% of incoming solar radiation.

Table 2: The soil physical characteristics of the experimental plot at different depths (0-40 cm).

Soil depth (cm)	Particle size distribution (%)			USDA textural class	Bulk density (g cm^{-3})	Field capacity (volumetric percentage)	Permanent wilting point (volumetric percentage)	Maximum water holding capacity (%)	Basic infiltration rate (cm h^{-1})	Hydraulic conductivity (cm day^{-1})
	Sand	Silt	Clay							
0 - 10	45.2	10.4	44.4	Sandy clay	1.50	42.26	23.14	54.18	1.47	11.31
10 - 20	46.7	9.8	43.5	Sandy clay	1.53	41.00	22.00	53.26		
20 - 30	50.1	8.2	40.2	Sandy clay	1.62	40.86	21.94	52.21		2.72
30 - 40	54.3	7.3	38.4	Sandy clay	1.72	40.21	21.32	51.94		

Table 3: The soil chemical characteristics of the experimental plot at different depths (0-40 cm).

Soil depth (cm)	pH	Electrical conductivity (1:2.5) (dS m^{-1}, 25 °C)	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
0 - 10	7.63	1.32	0.68	126.54	30.84	296.73
10 - 20	7.65	1.37	0.65	123.24	27.78	278.29
20 - 30	7.68	1.40	0.63	106.47	15.54	253.26
30 - 40	7.68	1.43	0.62	92.67	12.28	262.14

At 1:00 PM the soil temperature got raised by 1.93-1.22, 1.94-1.26 and 1.82-1.16 ºC at 3, 10 and 20 cm depths across all the treatments respectively. The maximum soil temperature fluctuation found in the treatments irrigation under non-mulched condition *i.e.*, T_2, T_4, T_6 andT_8 compared to the treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 andT_7 treatment. Snyder *et al.* (2015) also reported less fluctuation under plastic mulch than the bare soil during noon time. Reduced soil evaporation and condensation of vapour beneath the mulch material might have resulted in less warming under the mulches. The 10 cm depth got warmed up faster than other two depths in all the treatments. At 5:00 PM the temperature in different soil layers dropped by more than 1 ºC at the surface. The depletion in lower layers was less than 1 ºC in all the treatments.

The lower soil layers maintained higher temperature than the soil surface at different timings, which is accordance with the report of Kishore *et al.* (2018) for light silty loam soil during winter season. The highest temperature observations were recorded at 1:00 PM and the lowest temperatures were observed at 8:00 AM, which confirms the finding of Malo (2020). The fluctuation of morning and afternoon soil temperature at different depth might be due to heat flux in the soil as well as heat exchanges between the soil and atmospheric air. The similar trend was observed in Pawar *et al.* (2019); Deshmukh *et al.* (2013).

Soil temperature at 60 DAS. The data pertaining to soil temperature at 60 DAS was represented in Table 5. The results of the study clearly indicated that significant difference was observed among all the treatment at 3, 10 and 20 cm depth and timings. At 8:00 AM, lowest soil temperature recorded under the irrigation at 100% ET under non-mulched condition were 20.74, 22.36 and 23.33 ºC at 3, 10 and 20 cm, respectively. The irrigation at 80% FC under mulched condition treatment had higher temperature than the irrigation at 100% ET under non-mulched condition by 6.01, 5.57 and 5.22 ºC at 3, 10 and 20 cm depths, respectively due to the lower water application. At 1:00 PM, the temperatures in the top soil increased in the range of 4.48-5.52 ºC when compared to temperatures at 8:00 AM. The rise in temperature at 10 and 20 cm were ranges from 1.94-3.84ºC and 0.32-2.29ºC across the treatments, respectively. In contrast to observations at 30 DAS, the lower layers maintained lesser temperatures than the top soil at 1:00 PM. Again at 5:00 PM, temperatures were dropped by the range of 1.50-3.26ºC at 3 cm across treatments.

The lower depths maintained higher temperature than the surface in all the treatments at 5:00 PM, the transfer of heat from surface to sub surface soil might be the reason. The drop in temperatures at 10 and 20 cm were lesser compared to drop at 3 cm. The results are in accordance with the results of Deshmukh *et al.* (2013); Pawar *et al.* (2019).

Soil temperature at 90 DAS. Soil temperature differed significantly at 90 DAS due to different irrigation scenarios under mulched and non-mulched conditions for different depth and timings. At 90 DAS the lowest soil temperature recorded in the treatment response to irrigation at 100% ET under non-mulched condition were 24.86, 25.16 and 26.06 ºC at 3, 10 and 20 cm soil depths, respectively (Table 6). Similar to the temperature recorded from 30 and 60 DAS, the treatment irrigation at 80% FC under mulched condition maintained higher temperatures than other treatments at all the depths at 8:00 AM and 5:00 PM, due to prevention of heat loss from the soil by the mulch, but at 1:00 PM, the treatments irrigation under non-mulched condition *i.e.*, T_2, T_4, T_6 and T_8 maintained slightly higher temperatures *i.e.*, ranges from 1.14-1.64, 1.30-1.50 and 1.06-1.46 ºC over the treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 and T_7 at 3, 10 and 20 cm depths, respectively as open soil surface is more prone to air temperature fluctuations. The treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 and T_7 which ranges from 1.32-1.41 to 1.33-1.6 ºC higher temperature than the treatments irrigation under non-mulched condition *i.e.*, T_2, T_4, T_6 and T_8 at 3 cm depth in the morning and evening. At 1:00 PM, the temperatures were decreased with the soil depths in all the treatments, whereas in the morning and evening hours, the temperatures were gradually increasing in the lower soil layers. The surface soil layers were more affected by fluctuations in day time temperature, also the transfer of surface heat might help to retain higher temperature in lower soil layers during evening and night timings.

At 1:00 PM, the rise in temperature ranges from 3.81-4.13 ºC at 3 cm depths; 1.93-3.13 ºC at 10 cm depth; and 0.41-1.58 ºC at 20 cm depths across the treatments, respectively. At 5:00 PM, the surface and 10 cm of depth soil temperature dropped by 2.52-3.17 and 0.75-1.66 ºC across the treatments. The temperatures at 20 cm depths were increased by 0.09-0.74 ºC across the treatments compared to temperatures at 1:00 PM.

Among the all treatments, the treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 and T_7 kept the soil warm at all the depths of observations (3, 10 and 20 cm), than the T_2, T_4, T_6 and T_8. At 8:00 AM and 5:00 PM temperature under treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 and T_7 maintained a slightly higher temperature over the treatments irrigation under non-mulched condition *i.e.*, T_2, T_4, T_6 and T_8 at 1:00 PM, the temperature was the lowest in the treatment response to irrigation under non-mulched treatments.

Soil temperature at 103 DAS. Soil temperature was significantly influenced among all the treatments for different depth and timings at 103 DAS. At 8:00 AM the soil temperature at surface is lower compared to 10 and 20 cm depth under all the treatment. At the same time soil temperature has been found maximum irrigation at 80% FC under mulched condition *i.e.*, 31.27, 32.21 and 33.20 ºC followed by irrigation at 80% FC under non-mulched condition *i.e.*, 29.73, 31.00 and 31.95 ºC at 3, 10 and 20 cm (Table 7). The result concluded that at 8:00 AM the soil temperature in the treatment response to irrigation at 80% FC under mulched condition was 6.29, 5.84 and 5.88°C higher than in the treatment response to irrigation at 100% FC under non-mulched condition at 3, 10 and 20 cm depth respectively. The result revealed that during forenoon soil temperature increases with increasing depth.

Based on the recorded data at 1:00 PM, the soil temperature at 5 cm depth is higher compared to 10 and 20 cm depth under all the treatments. The temperature has been found maximum in the treatment response to irrigation at 80% FC under mulched condition and the lowest temperature observed in the treatment response to irrigation at 100% FC under non-mulched condition at 3, 10 and 20 cm depth. The result revealed that at afternoon soil temperature decreases with increasing depth. Variation of soil temperature in treatments response to irrigation under non-mulched condition *i.e.*, T_2, T_4, T_6 and T_8 was higher ranges from 4.85-5.02, 2.24-2.53 and 0.56-0.83 ºC at 1.00 PM was measured at 3, 10 and 20 cm depth when compared to treatments irrigation under mulched condition *i.e.*, T_1, T_3, T_5 and T_7. At 5:00 PM, the surface and 10 cm of depth soil temperature decreased by 2.71-3.30 ºC and 0.39-1.29 ºC respectively, across the treatments. Temperatures at 20 cm depths were raised by 0.09-0.98 ºC across the treatments, when compared to temperatures at 1:00 PM. The results are in conformity with the findings of Chawla *et al.* (2009); Ramakrishna *et al.* (2006).

The trend of soil temperature variation between irrigation under mulched and non-mulch conditions at different growth stages of ridge gourd observed in the study is also similarly reported by Malo (2020); Pawar *et al.* (2019); Deshmukh *et al.* (2013); Monks *et al.* (1997); Diaz-Perez *et al.* (2004); Chawla *et al.* (2009); Gupta *et al.* (2013) and Job *et al.* (2016) and many others. The fluctuations in temperature at 10 and 20 cm depth were less between the different hours of observations as compared to surface layers. The lowest soil temperatures were recorded at 8:00 AM. The presence of air between the soil and mulch sheets might have reduced the temperature fluctuations during noon time, the vapour present under the mulch may also helped to keep the temperature low during noon time. The poor heat conductivity of air might have reduced the heat loss during night time, which probably resulted in higher temperature during morning under mulched conditions. The findings of Shaikh and Fouda (2008) and Ham *et al* (1993) confirm the same. The increased average soil temperature and reduced fluctuations of diurnal soil temperature under white mulch compared to non-mulched condition was reported to be beneficial for good crop establishment (Snyder *et al.*, 2015).

Table 4: Soil temperature (ºC) as influenced by different irrigation scenarios under mulched and non-mulched conditions at 30 DAS of ridge gourd.

Treatment details	At 8:00 am			At 1:00 pm			At 5:00 pm		
	Soil depth			Soil depth			Soil depth		
	3 cm	10cm	20 cm	3 cm	10cm	20 cm	3 cm	10cm	20 cm
T_1	26.54	27.79	28.76	28.04	29.10	30.08	27.00	28.21	29.21
T_2	25.12	26.55	27.84	26.83	28.31	29.28	25.76	27.45	28.45
T_3	29.84	31.14	32.04	31.28	32.46	33.30	30.26	31.54	32.52
T_4	28.28	29.54	30.70	30.14	31.48	32.34	29.00	30.52	31.47
T_5	24.90	26.22	27.15	26.12	27.48	28.36	25.02	26.58	27.42
T_6	23.60	24.80	26.00	25.53	26.64	27.82	24.42	25.76	26.98
T_7	28.18	29.45	30.36	29.66	30.73	32.04	28.54	29.86	31.22
T_8	27.00	28.30	29.58	28.73	29.84	30.68	27.65	28.96	29.86
S.Em±	**0.95**	**1.10**	**1.11**	**1.03**	**1.13**	**1.07**	**1.04**	**1.03**	**1.13**
C. D. @ 5%	**2.89**	**3.33**	**3.37**	**3.13**	**3.42**	**3.24**	**3.15**	**3.13**	**3.43**

Table 5: Soil temperature (ºC) as influenced by different irrigation scenarios under mulched and non-mulched conditions at 60 DAS of ridge gourd.

Treatment details	At 8:00 am			At 1:00 pm			At 5:00 pm		
	Soil depth			Soil depth			Soil depth		
	3 cm	10cm	20 cm	3 cm	10cm	20 cm	3 cm	10cm	20 cm
T_1	23.77	25.01	25.82	28.83	28.15	27.57	25.93	27.20	28.01
T_2	22.51	23.79	24.49	27.44	26.67	26.03	24.42	25.93	26.71
T_3	26.75	27.93	28.55	32.27	31.77	30.84	29.01	30.24	31.05
T_4	25.29	26.55	27.31	30.73	30.11	29.45	27.62	28.81	29.59
T_5	22.44	23.82	24.56	27.31	26.23	25.63	24.28	25.49	26.41
T_6	20.74	22.36	23.33	26.22	25.30	24.65	23.72	24.87	25.62
T_7	25.20	26.38	27.11	30.61	29.89	29.20	27.50	28.72	29.19
T_8	23.91	25.04	25.93	29.06	28.38	27.85	26.03	27.47	28.28
S.Em±	**1.08**	**1.07**	**1.09**	**1.06**	**1.04**	**1.06**	**1.26**	**1.25**	**1.22**
C. D. @ 5%	**3.28**	**3.24**	**3.31**	**3.22**	**3.14**	**3.20**	**3.83**	**3.78**	**3.71**

Table 6: Soil temperature (ºC) as influenced by different irrigation scenarios under mulched and non-mulched conditions at 90 DAS of ridge gourd.

Treatment details	At 8:00 am			At 1:00 pm			At 5:00 pm		
	Soil depth			Soil depth			Soil depth		
	3 cm	10cm	20 cm	3 cm	10cm	20 cm	3 cm	10cm	20 cm
T_1	27.74	29.02	29.95	31.60	31.24	30.61	29.08	30.49	31.35
T_2	26.33	27.63	28.57	30.46	29.94	29.22	27.67	29.11	29.89
T_3	31.00	32.33	33.25	34.81	34.38	33.66	32.08	33.22	33.98
T_4	29.68	30.96	31.92	33.63	32.89	32.60	30.48	31.93	32.69
T_5	26.20	27.42	28.32	30.10	29.69	29.06	27.50	28.65	29.42
T_6	24.86	25.16	26.06	28.79	28.29	27.64	25.90	27.37	28.19
T_7	29.37	30.64	31.55	33.45	32.91	32.26	30.28	31.78	32.82
T_8	28.00	29.38	30.29	31.81	31.41	30.80	28.95	30.49	31.23
S.Em±	**1.39**	**1.57**	**1.58**	**1.38**	**1.36**	**1.39**	**1.33**	**1.31**	**1.33**
C. D. @ 5%	**4.23**	**4.76**	**4.78**	**4.19**	**4.12**	**4.22**	**4.04**	**3.99**	**4.03**

Table 7: Soil temperature (ºC) as influenced by different irrigation scenarios under mulched and non-mulched conditions at 103 DAS of ridge gourd.

Treatment details	At 8:00 am			At 1:00 pm			At 5:00 pm		
	Soil depth			Soil depth			Soil depth		
	3 cm	10cm	20 cm	3 cm	10cm	20 cm	3 cm	10cm	20 cm
T_1	27.96	29.33	30.63	32.88	31.74	31.06	29.67	30.46	31.45
T_2	26.53	27.77	28.77	31.53	30.27	29.33	28.45	29.21	30.13
T_3	31.27	32.21	33.20	36.04	34.21	33.78	33.04	33.82	34.76
T_4	29.73	31.00	31.95	34.75	33.53	32.68	31.45	32.24	33.18
T_5	26.46	27.72	28.67	31.05	29.96	29.29	28.34	29.15	29.38
T_6	24.98	26.37	27.32	29.82	28.61	28.02	26.83	27.91	28.87
T_7	29.67	30.96	31.92	34.47	33.30	32.70	31.37	32.05	32.99
T_8	28.08	29.42	30.42	32.93	31.77	31.25	29.94	30.65	31.60
S.Em±	**1.44**	**1.36**	**1.39**	**1.42**	**1.38**	**1.58**	**1.36**	**1.40**	**1.42**
C. D. @ 5%	**4.35**	**4.11**	**4.20**	**4.31**	**4.19**	**4.79**	**4.14**	**4.24**	**4.32**

2. Weed density. A square portion measuring 1 m × 1 m was chosen in each treatment. The number of weeds per m^{-2} was taken into account after the weed population in each treatment was enumerated at 30, 60, 90 and 103 DAS during 2021-22 and 2022-23 (Table 8).

The different Irrigation scenarios under mulched and non-mulched conditions influenced the weed density significantly during the period of the crop growth. The treatment pertaining to irrigation at 100% ET under non-mulched (T_6) recorded significantly higher weed density *i.e.,* 34.67, 34.17, 33.50 and 31.00 at 30, 60, 90 and 103 DAS, respectively on pooled basis followed by irrigation at 100% FC under non-mulched (T_2). While irrigation at 80% FC under mulched (T_3) had lower weed density *i.e.,* 9.67, 8.17, 6.50 and 6.00 at 30, 60, 90 and 103 DAS, respectively on pooled basis, which was 72.11, 76.09, 80.60 and 80.65% lesser than the irrigation at 100% ET under non-mulched (T_6). Similar trend were also reported by Bobby *et al.* (2017); Kumar *et al.* (2020). The treatment irrigation at 100% ET under non-mulched (T_6) had higher weed density when compared to all other treatments due to the higher amount of water applied in this treatment. The weed growth at 30 DAS was slightly higher than those at 60 and 90 DAS in all the treatments, as the sparse crop cover, open soil surface and frequent irrigations may encourage free weed growth. At 103 DAS, the weed growth significantly reduced in all the treatments. Similar results have been earlier reported by Kumar *et al* (2020).

Irrigation with plastic mulch restricted weed growth to the area where pores were made for sowing the seed, as the remaining area of the bed was thermally insulated and the mulch cover blocked light from reaching the soil surface. The non-mulched beds, had more weed growth, offered more competition to the crop. The results were in agreement with the findings of Kishore *et al.* (2018); Kumar *et al.* (2020).

3. Fruit yield per plant (kg). The fruit yield per plant of ridge gourd as influenced significantly by different irrigation scenarios under mulched and non-mulched conditions is presented in Table 9.

The fruit yield per plant differed significantly due to irrigation scenarios under mulched and non-mulched conditions. Significantly higher fruit yield per plant was observed in T_1*i.e.,* irrigation at 100% FC under mulched condition on pooled basis (6.14 kg), followed by irrigation at 100% ET under mulched condition (T_5) *i.e.,* 5.56 kg. Lowest fruit yield per plant was observed in T_4 *i.e.,* irrigation at 80% FC under non-mulched condition on pooled basis (3.18 kg).

Adequate soil moisture levels facilitated by sensor irrigation can improve nutrient uptake by the plants, ensuring that ridge gourd plants receive the necessary nutrients required for healthy fruit development. Sensor irrigation can also help in preventing water-related diseases, as the system allows for targeted water application and avoids waterlogging, which could promote certain plant diseases. The results are in accordance with the findings of Borugh (2019).

4. Fruit yield per plot (kg). The influence of different irrigation scenarios under mulched and non-mulched conditions on fruit yield per plot of ridge gourd is presented in Table 9.

Among different Irrigation scenarios under mulched and non-mulched conditions significantly higher fruit yield per plot was observed in T_1 *i.e.,* irrigation at 100% FC under mulched condition on pooled basis (98.26 kg), followed by irrigation at 100% ET under mulched condition (T_5) *i.e.,* 89.01 kg. Lower fruit yield per plot was observed in T_4 *i.e.,* irrigation at 80% FC under mulched condition on pooled basis (50.80 kg).

The enhanced supply of nutrients through the optimum irrigation levels at the root vicinity of plant, maintains optimum nutrient concentration in the root zone throughout the crop growth period. This increases the uptake of moisture and nutrients which resulted in increased yield attributes. Similar result was also reported by Choudhari and More (2002); Kumar and Dwivedi (2018); Surve *et al.* (2002) for cultivation of cucurbits in open field.

5. Crop yield per hectare (t ha^{-1}). The data recorded on crop yield per hectare in ridge gourd as influenced by different irrigation scenarios under mulched and non-mulched conditions is presented in Table 9.

Crop yield per hectare was significantly higher in the treatment pertaining to irrigation at 100% FC under mulched condition (T_1) on pooled basis (45.49 kg ha^{-1}) followed by treatment irrigation at 100% ET under mulched condition (T_5) *i.e.,* 41.21 kg ha^{-1}. In contrast, the treatment involving irrigation at 80% FC under non-mulched condition (T_4) recorded significantly lower crop yield per hectare on pooled basis (23.52 kg ha^{-1}).

Higher yield can be attributed to maintenance of field capacity at root zone. The root development was observed to be higher in sensor based irrigation. Proper irrigation management is acquired by the sensor based irrigation system which can ensure that ridge gourd plants receive adequate water during the critical growth stages, leading to healthier and more vigorous growth and minimize the water related stress factor. The results are in conformity with the findings of Apparao *et al.* (2015); Rahil *et al.* (2015).

C. Gross income and Benefit cost ratio

Benefit cost ratio (BC ratio) was calculated as a ratio of gross return from the project to the cost involved in implementation of the project. BC ratio of more than one is desirable for its recommendation. The highest BC ratio of 1.90 was observed under surface drip irrigation at 100% ET under mulched condition (T_5) because of lower cost of cultivation, followed by sensor based drip irrigation at 100% FC under mulched condition (T_1), *i.e.,* 1.87. Whereas, sensor based drip irrigation at 80% FC under non-mulched condition (T_4) recorded lowest BC ratio *i.e.,* 1.01. Though the BC ratio is high in surface drip irrigation at 100% ET under mulched condition (T_5) but the WUE was found to be high in sensor based drip irrigation at 100% FC under mulched condition (T_1). These results are nearly conformity with the Sharma (2021).

Sensor based irrigation provides a real-time data provided by sensors enables farmers to customize irrigation schedules based on the specific needs of each crop and its growth stage. This level of precision ensures that crops get the right amount of water at the most critical growth periods. Although initial setup costs may be higher, the long-term benefits of reduced water usage, increased yields and minimized labour expenses result in substantial cost savings for the farmers. The higher benefit cost ratio was attributed to higher gross returns with lower cost of cultivation. The results are presented in Table 9.

Table 8: Influence of different irrigation scenarios on weed density (m^{-2}) at different growth stages of ridge gourd under mulched and non-mulched conditions (pooled data).

Treatment details	Weed density (m^{-2})											
	30 DAS			60 DAS			90 DAS			103 DAS		
	2021-22	2022-23	Pooled data	2021-22	2022-23	Pooled data	2021-22	2022-23	Pooled data	2021-22	2022-23	Pooled data
T_1	10.67	11.33	11.00	10.00	10.67	10.33	9.33	10.00	9.67	7.00	8.67	7.83
T_2	31.33	30.67	31.00	29.33	29.67	29.50	28.33	29.00	28.67	26.67	27.00	26.83
T_3	8.67	10.67	9.67	7.67	8.67	8.17	6.33	6.67	6.50	5.67	6.33	6.00
T_4	27.67	26.33	27.00	26.33	23.67	25.00	24.00	23.67	23.83	23.00	22.33	22.67
T_5	11.67	12.67	12.17	11.33	12.00	11.67	11.33	12.67	12.00	8.67	9.67	9.17
T_6	34.33	35.00	34.67	34.33	34.00	34.17	33.67	33.33	33.50	30.33	31.67	31.00
T_7	9.67	11.67	10.67	8.67	10.33	9.50	7.00	7.67	7.33	6.33	7.67	7.00
T_8	29.00	30.33	29.67	27.67	26.33	27.00	27.33	26.67	27.00	24.67	24.33	24.50
S.Em±	**0.96**	**0.80**	**0.78**	**0.70**	**0.76**	**0.79**	**0.80**	**0.68**	**0.66**	**0.68**	**0.68**	**0.64**
C. D. @ 5%	**2.92**	**2.41**	**2.35**	**2.11**	**2.31**	**2.38**	**2.42**	**2.06**	**1.99**	**2.06**	**2.06**	**1.94**

Table 9: Fruit yield per plant (kg), fruit yield per plot (kg) and crop yield (t ha^{-1}) of ridge gourd as influenced by different irrigation scenarios under mulched and non-mulched conditions.

Treatment Details	Fruit yield per plant (kg)			Fruit yield per plot (kg)			Crop yield (t ha^{-1})			Benefit ratio
	2021-22	2021-22	Pooled data	2021-22	2021-22	Pooled data	2021-22	2022-23	Pooled data	Pooled data
T_1	6.25	6.03	6.14	99.96	96.55	98.26	46.28	44.70	45.49	1.87
T_2	5.81	5.29	5.55	92.99	84.63	88.82	43.05	39.18	41.12	1.76
T_3	3.71	3.43	3.57	59.29	54.82	57.07	27.45	25.38	26.42	1.09
T_4	3.17	3.18	3.18	50.72	50.89	50.80	23.48	23.56	23.52	1.01
T_5	5.83	5.30	5.56	93.27	84.76	89.01	43.18	39.24	41.21	1.90
T_6	5.09	4.78	4.93	81.39	76.46	78.93	37.68	35.40	36.54	1.76
T_7	4.48	4.21	4.35	71.71	67.35	69.53	33.20	31.18	32.19	1.48
T_8	4.06	3.80	3.93	64.91	60.80	62.86	30.05	28.15	29.10	1.40
S.Em±	**0.22**	**0.20**	**0.21**	**3.42**	**2.99**	**3.01**	**1.53**	**1.36**	**1.42**	1.87
C. D. @ 5%	**0.67**	**0.61**	**0.63**	**10.36**	**9.08**	**9.13**	**4.65**	**4.12**	**4.32**	1.76

CONCLUSIONS

The present investigated the impact of sensor-based irrigation system under mulched on ridge gourd. The main aim of this study was to analyze the water saving potential, crop yield improvement and overall sustainability of this integrated approach.

Different irrigation scenarios under mulched and non-mulched conditions significantly influenced the diurnal variation in soil temperature at different soil depths during different crop growth stages. The treatments under mulched condition maintained higher soil temperatures at 3, 10 and 20 cm soil depths at 8:00 AM, 1:00 PM and 5:00 PM, at 30, 60 and 90 DAT of the crop. The soil temperature was about 1.42, 1.42 and 1.34 ºC higher than the irrigation under non-mulched condition at 3, 10 and 20 cm soil depths. At 1:00 PM, the soil at 3, 10 and 20 cm depths under irrigation under mulched treatments (maintained higher temperature than the irrigation under non-mulched condition by 1.26, 1.24 and 1.24 ºC, respectively. At 5:00 PM, the increase in temperature under irrigation under mulched treatments were 1.29, 1.17 and 1.15 ºC than the irrigation under non-mulched condition at 3, 10 and 20 cm soil depths, respectively. Maximum weeds were found in irrigation at 100% ET under non-mulched treatment compared to the irrigation at 80% FC under mulched treatments. Lower irrigation throughout the crop period with polyethylene mulch, controlled the weed population, and saved the inter cultivation cost. The weed per metre square in under non-mulched plots, was found to be higher throughout the crop period.

Crop yield per hectare was significantly higher in the treatment pertaining to irrigation at 100% FC under mulched condition on pooled basis (45.49 kg ha^{-1}), followed by treatment under irrigation at 100% ET under mulched condition (T_5) *i.e.*, 41.21 kg ha^{-1}. In contrast, the treatment involving irrigation at 80% FC under non-mulched condition recorded significantly lower crop yield per hectare on pooled basis (23.52 kg ha^{-1}). The growth yield parameters of the ridge gourd recorded highest in treatment pertaining to irrigation at 100% FC under mulched condition (T_1), *i.e.*, fruit length of 53.07 cm, fruit girth of 17.32 cm, fruit weight of 348.20 g and fruit yield per plant of 6.25 kg on pooled basis.

Highest net present worth of ₹ 29,88,351 ha^{-1} was observed under sensor based drip irrigation at 100% FC under mulched condition. The net present worth from sensor based drip irrigation at 100% FC and surface drip irrigation at 100% ET under mulched condition were 17.54 and 10.59% higher than the sensor based drip irrigation at 80% FC under non-mulched condition. The surface drip irrigation system at 100% evapotranspiration (ET) in mulched conditions yielded the greatest benefit-cost ratio, i.e., 1.90. The treatment of surface drip irrigation at 100% ET under mulched condition resulted in observed payback times of 0.47 years, indicating a very short time frame for recouping the initial investment. The implementation of a sensor-based drip irrigation system, along with mulching, is a financially feasible solution that may be offered to farmers operating in arid and semi-arid regions. Despite the higher initial setup costs, farmers may achieve significant cost savings in the long run due to lower water consumption, better yields, and minimised labour requirements.

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