Original Research Article

Influence of plastic mulching and irrigation levels on soil temperature, moisture and water use efficiency of tomato crop (*Solanum lycopersicum*)

Abstract

Farmers in India rarely employ plastic mulches in tomato cultivation, despite the fact that it has the potential to save irrigation water, manage weeds, and increase output. The precision of irrigation water for tomato production using various colour plastic mulches was evaluated in an experimental farm at UAS-Raichur. Because of the effect of irrigation levels, the 120 percent evapotranspiration based irrigation treatment had the most soil moisture availability, while the 60 percent evapotranspiration irrigation by drip had the lowest, and optimal soil moisture was maintained using plastic colour mulches. The maximum temperature was recorded in white on black plastic colour mulch (3.69^0C), which absorbs 100 percent of solar radiation, and the highest temperature was measured in black plastic colour mulch (3.69^0C), which absorbs 100 percent of solar radiation (2.25^0C). The water use efficiency was highest when 80 percent ET was combined with white on black plastic colour mulch (26.77 kg/m^3).

Key words: Irrigation water, precision, evapotranspiration, water use efficiency

1. Introduction

Plasticulture, or the use of plastic mulch in agriculture, is becoming increasingly popular in Indian agriculture to increase crop productivity. Today, agricultural tactics are oriented towards increasing crop output through environmentally sensitive technologies and better water management by using high-yielding varieties, intensive fertilizer, and pesticides. The use of mulch over the soil surface maintains a beneficial soil-water-plant relationship. Mulch has a considerable impact on the physical soil structure, moisture, erosion, thermodynamic environment, insect and disease incidence, crop growth, and yield in the microclimate around the plant and soil. Organic mulches are commonly employed in our nation for moisture conservation and soil temperature regulation, but they only affect weed growth. The disadvantages of organic mulch can be illustrated by the fact that it would take 50 m3 to spread sawdust 2.54 cm deep over 20 percent of a hectare. A similar amount of plastic mulch film would cover more than 250 hectares. The impermeability of plastic mulch, which limits direct moisture evaporation from the soil and reduces water losses, is a major benefit (Akbari et al., 2009). Plastic mulch has been made out of HDPE, LDPE, and LLDPE. Plastic LDPE mulches are most typically employed in the above categories. LLDPE has recently outperformed LDPE as a mulch material due to its two linked qualities of greater down gauging and puncture resistance and the fact that it inhibits weed development. Several novel colours - yellow, silver, green, red, and infrared transmitting mulch - have been studied for early tomato production in various parts of India (Rudich, et al, 1978). The results have been inconsistent year to year, especially with mulch colours. Irrigated agriculture has major issues that threaten its appropriateness as the globe becomes increasingly reliant on the production of irrigated lands. It is prudent to make optimum use of current water resources and bring additional land under irrigation. This can be accomplished by implementing modern and sophisticated irrigation systems as well as better water management procedures (Zaman et al., 2001). Mulching is one of the management strategies for boosting water use efficiency. Mulch is any material that is spread on the soil's surface to protect it from rain, sun radiation, or evaporation. Mulch is made up of a variety of materials such as wheat straw, rice straw, plastic film, grass, wood, sand, and so on (Khurshid et al., 2006). Mulch improves the soil environment by lowering soil temperature (Sarkar and Singh, 2007), increasing soil porosity and water penetration during heavy rain (Glab and Kulig, 2008), and reducing runoff and soil erosion (Glab and Kulig, 2008). (Bhatt and Khera, 2006). In both the on-season and off-season, vegetable cultivation is one of the burgeoning industries in India. The income is significantly higher than that of other crops, ranging from 3 to 5 times that of other crops. There has been an effort to enhance productivity per unit area. Tomatoes *(lycopersicon* *esculentum)* are the Solanaceae family's Lycopersicon genus. Tomato is a herbaceous, sprawling plant with a weak woody stem that grows to a height of 1-3 m. The flowers are yellow, and the fruits of cultivated cultivars range in size from 1–2 cm in diameter cherry tomatoes to 10 cm or more in diameter beefsteak tomatoes. When ripe, most varieties produce crimson fruits. The tomato is a Peruvian and Mexican native. Though there are no definitive records of when and how it arrived in India, the Portuguese may have been responsible. Because of their high nutritional value, tomatoes are one of the most significant "protective foods." It is one of the most adaptable vegetables with a wide range of applications in Indian cuisine. Tomatoes are used in soups, salads, pickles, ketchup, puree, sauces, and various other dishes. They can also be eaten raw as a salad vegetable. In light of the preceding, a field trial was conducted from 2015 to 2016 at the College of Agricultural Engineering, Raichur, utilizing the widely used US-800 (Jawari) tomato variety.

2. Material and Methods

2.1 Experimental area

Raichur is located in the Northeastern Dry Zone, which is part of Karnataka's Region 1's Zone II. This site is at an elevation of 389 meters above mean sea level and is located at 16 15' N latitude and 77 20' E longitude (MSL). The field experiment was designed as a split plot with three replications, four main treatments, and four sub treatments. The experimental field has clay textured soil and a pH of 7.9 and a good electrical conductivity of 0.98 dS m^{-1} (**Table 1).** Before transplanting, soil has available nitrogen (180 kg ha^{-1}), phosphorous (15.3 kg ha^{-1}), and potassium (98.10 kg ha^{-1}). After harvesting, the soil has available nitrogen (162.5 kg ha^{-1}), phosphorous (14.85 kg ha^{-1}) and potassium (96.10 kg ha^{-1}). Each treatment combination resulted in a single seedling being planted. From the 5th day after transplanting to the 10th day, the mortality of the seedlings in the field was monitored, and gap filling was done using seedlings from the same nursery to maintain the appropriate plant density.

2.2 Treatment details

Four-irrigation levels and four mulch treatments were included to fulfil the objectives of the study –

- Main treatments

  I_1- water application at 60 per cent ET using drip irrigation

  I_2- water application at 80 per cent ET using drip irrigation

  I_3- water application at 100 per cent ET using drip irrigation

  I_4- water application at 120 per cent ET using drip irrigation

- Sub-treatments

  M_0 –without mulch

  M_1– White on black

  M_2 – Silver on black

  M_3 –Black plastic mulch

2.3 Irrigation source and its quality, scheduling

The irrigation water utilized in the experiment was pond water from a farm. The water was tested for irrigation suitability. Irrigation water had a pH of 7.82 and an electrical conductivity (EC) of 0.85 dS m^{-1}. The irrigation was then delivered according to the irrigation treatments.

2.4 Soil moisture studies

2.5 Before irrigation, the moisture content of soil samples from various irrigation levels was evaluated at a depth of 10 cm. Standard procedures were used to collect samples at 30, 60, 90, and 120 DAT. The soil moisture was determined using the gravimetric method.

Soil temperature

The temperature of the soil was measured in the afternoon. The temperature of the soil was observed with a thermometer at the surface and at a depth of 10 cm with and without mulch treatments. At the same time, the temperature of the atmosphere was measured. **Water use efficiency (WUE)**

For drip irrigation methods, the water use efficiency of each treatment was calculated using the formula below.

$$e_u = \frac{Y}{WR} \qquad \ldots (1)$$

Where,

e_u = Water use efficiency, (kg m^{-3})

Y = Crop yield, (kg)

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

3. Results and Discussions

3.1 Soil Moisture

The maximum soil moisture content (18.08), was observed in treatment I_4M1 followed by I_4M_3 (18.02), I_3M_1 (17.97) at 30 DAT. Similarly, 60 DAT, treatment I_4M_1 recorded the maximum soil moisture content (16.79), whereas treatment I_1M_0 recorded the least soil moisture content (14.52). 90 days later, treatment I_4M_1 recorded the maximum soil moisture level(18.33), while treatment I_1M_0 recorded the smallest soil moisture content (16.06). Finally, 120 DAT, treatment I_4M_1 recorded the maximum soil moisture content(17.28), while treatment I_1M_0 recorded the least soil moisture content (15.01). Because of the effect of irrigation levels, the 120 percent ET irrigation treatment had the most soil moisture availability, while the 60 percent ET irrigation by drip had the lowest, and optimal soil moisture was maintained using plastic colour mulches **(Table 2)**. This is because moisture distribution under drip irrigation is a three-dimensional function that includes vertical, lateral, and diagonal movements, whereas moisture distribution under surface irrigation is a one-directional movement (Badr, 2007).

3.2 Soil temperature

It may be deduced that the average soil temperature recorded at ground surface level in the afternoon hours was 33.91^{0}C, compared to an ambient temperature of 32.75^{0}C. In comparison to the ambient temperature of 32.75^{0}C, the greatest average soil temperature was found in the black plastic mulch treatment throughout the crop season (36.44^{0}C), followed by silver on black mulch (35.46^{0}C), and finally white on black plastic mulch (35.00^{0}C). It may also be deduced that the average soil temperature at ground surface level during the afternoon hours was 1.16^{0}C higher than the ambient temperature. When compared to the average atmospheric temperature, the black plastic mulch treatment had the greatest average soil temperature (3.69^{0}C higher), followed by silver on black mulch (2.71^{0}C higher), and finally white on black plastic mulch (2.25^{0}C higher). Increased radiation absorption and greater heat conductivity between the soil surface and the plastic mulch could explain the higher soil temperature under plastic colour mulches. These findings are consistent with Tapani et al (2015).

3.3 Water use efficiency (WUE)

The results show that treatment I_2M_1 had the highest WUE (26.77 kg/m3), followed by I_2M_2 (25.09 kg/m3) and I_1M_1 (24.52 kg/m3). Similarly, treatment I4M3 had the lowest WUE (10.76 kg/m3). Treatment I_2M_1 had the highest WUE (25.47 q/ha-cm) in terms of yield achieved per unit depth of water applied **(Table 3)**. This was owing to the fact that white and silver plastic colour mulch created a better environment for plant height, leaf population, and leaf metabolic activities, resulting in a higher crop production with the same water application rate as non-mulched treatments and temperature effects. The current findings are consistent with those of and Patil and Patil (2009), as well as Baye Berihun (2011).

4. Conclusion

Soil moisture can be maintained optimum by using plastic colour mulches in areas with high evaporation rates. The highest soil moisture was in mulched plots than the without mulched plot. The plastic sheet captured the water vapours from the soil, resulting in water vapour that fell back into the upper soil layer. As a result, the soil's moisture retention capacity improves as evaporation losses are reduced. Plastic mulches are often used to change soil temperature and moisture regimes, suppress weeds, prevent insect migration, and possibly influence the plant's photobiology. Plastic mulches largely influence the field microclimate by altering the surface's radiation budget. These microclimate elements have a significant impact on the temperature and moisture of the soil in the root zone, which can affect plant development and productivity. The black mulch treatment, with a water use efficiency of 120 percent 10.76 kg/m^3, had the lowest water use efficiency.

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Table 1. Soil characteristics of the experimental plot

Soil characteristics	Particulars	Composition
Textural composition	Sand, (percent)	14.68
	Silt, (percent)	40.10
	Clay, (percent)	46.32
Chemical properties	Available N, Kg/ha	180
	Available P_2O_5, Kg/ha	15.3
	Available K_2O, Kg/ha	98.10
	pH	7.90
	EC (dSm^{-1})	0.98
Physical properties	Bulk density, g/cc	1.42

	Field capacity, per cent	23.15
	Permanent wilting point, per cent	10.22
	Infiltration rate, cm/hr	1.53

Table 2. Effect of different irrigation levels and plastic colour mulches on soil moisture content at different DAT

Treatments	30 DAT				60 DAT				90 DAT				120 DAT			
	M_0	**M_1**	**M_2**	**M_3**	**M_0**	**M_1**	**M_2**	**M_3**	**M_0**	**M_1**	**M_2**	**M_3**	**M_0**	**M_1**	**M_2**	**M_3**
I_1	15.81	16.77	16.22	16.09	14.52	15.48	14.93	14.80	16.06	17.02	16.47	16.34	15.01	15.97	15.42	15.29
I_2	16.42	17.86	17.63	17.16	15.13	16.64	16.35	15.88	16.67	18.18	17.89	17.42	15.62	17.13	16.84	16.37
I_3	17.08	17.97	17.74	17.44	15.79	16.69	16.45	16.15	17.33	18.23	17.99	17.69	16.62	17.18	16.94	16.64
I_4	17.21	18.08	17.83	18.02	15.92	16.79	16.54	16.74	17.46	18.33	18.08	18.28	16.41	17.28	17.03	17.23
Mean	16.63	17.97	17.73	17.54	15.61	16.71	16.45	16.26	17.15	18.25	17.99	17.80	16.22	17.20	16.94	16.75
	SEM		CD @5percent		SEM		CD @5percent		SEM		CD @5percent		SEM		CD @5percent	
	0.55		NS		0.40		NS		0.40		NS		0.37		NS	

Table 3. Effect of different irrigation levels and plastic colour mulches on crop WUE

Treatments	Yield obtained (q/ha)	Crop WUE (kg/m^3)
I_1M_0	604.93	23.04
I_1M_1	643.88	24.52
I_1M_2	614.22	23.39
I_1M_3	564.04	21.48
I_2M_0	703.14	20.13
I_2M_1	935.45	26.77
I_2M_2	876.53	25.09
I_2M_3	731.56	20.94
I_3M_0	712.13	16.33
I_3M_1	836.00	19.17
I_3M_2	752.49	17.25
I_3M_3	611.84	14.03
I_4M_0	584.74	11.18
I_4M_1	628.40	12.02
I_4M_2	582.58	11.14
I_4M_3	562.71	10.76