Biological Forum – An International Journal 13(4): 1286-1291(2021)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Hydrothermal conditions of Cotton Field under different Irrigation Levels and Mulches

Shri Rakesh[1*], S.R. Bhunia[2], S.M. Kumawat[3], N.K. Pareek[4], R.S. Rathore[5] and Amaratpal Singh[6]
[1]Ph.D. Research Scholar, Department of Agronomy, College of Agriculture, Bikaner, (Rajasthan), India.
[2]Professor & Head, Department of Agronomy, College of Agriculture, Bikaner, (Rajasthan), India.
[3]Professor, Department of Agronomy, College of Agriculture, Bikaner, (Rajasthan), India.
[4]Assistant Professor, Department of Agronomy, College of Agriculture, Bikaner, (Rajasthan), India.
[5]Associate Professor (Horticulture), Agricultural Research Station, Bikaner, (Rajasthan), India.
[6]SRF (Horticulture), College of Agriculture, Bikaner, (Rajasthan), India.

(Corresponding author: Shri Rakesh)*
(Received 21 September 2021, Accepted 27 November, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Water scarcity is one of the main problems to be challenged by the world. Improper management has contributed extensively to the current water scarcity and is also a serious challenge to future food security and environmental sustainability. During the hot summer days (May–August), high soil temperature accelerates evaporation at soil surface and reduces soil moisture, with a consequent negative impact on the growth and development of the crop. For satisfactory yield, it is necessary to conserve soil moisture and modify soil temperature for the cultivation of cotton. A field experiments were conducted consecutively for two years during *kharif* season of 2019 and 2020 at Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The experiment comprising total 20 treatment combinations; five level of irrigation (0.30 PE, 0.45 PE, 0.60 PE, 0.75 PE and 0.75 IW/CPE ratio) and four mulches (no mulch, dust mulch, straw mulch and polythene mulch) in split plot design with three replications. Results of the investigation revealed that increase in irrigation water also increase soil moisture content at 0-15 cm and 15-30 cm soil depth and reduce soil temperature. Higher soil moisture content was maintained under plot irrigated at 0.75 PE followed by 0.60 PE through drip irrigation during both the years. Among mulch treatments, polythene mulched plots retained higher soil moisture and observed higher soil temperature followed by straw mulch during both the years. Straw mulch observed lower soil temperature as compared to no mulch, dust mulch and polythene mulch.

Keywords: Cotton, Drip irrigation, Mulch, Soil moisture, Soil temperature.

INTRODUCTION

Cotton, the white gold is the world's leading fibre crop plays important role in economics of the world and also considered as the fourth most important oilseed. Cotton production, processing and trade provide livelihood and employment to several millions of people. Globally cotton production is 118.5 million bales in 2018-19 (USDA, 2019). India is the second largest producer after china in the world. In India, it is cultivated in 13.37 million hectares with an annual production of 35.49 million bales and productivity of 386 kg ha^{-1} in 2019-20 (Anonymous, 2020a). It is mostly cultivated in the states of Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu. In Rajasthan, Sri Ganganagar, Hanumangarh, Bhilwara, Banswara, Nagaur, Jodhpur, Alwar, Bikaner and Ajmer are major cotton growing districts. The crop occupied 7.60 lakh hectares area and produced 27.87 lakh bales with the productivity 623 kg ha^{-1} in 2019-20 (Anonymous, 2020b).

Cotton farming on light soils with poor organic matter, available nutrient status, low water retention capacity, and high evaporation is related with low yields in arid western Rajasthan. In these circumstances, good irrigation water management through the use of a drip system and mulch can be a useful intervention in increasing water productivity. With the rising cost of water and the ever-dwindling availability of water for crops, obtaining optimum crop growth and yield per unit of applied water has become more crucial.

Agricultural management strategies can affect the hydrothermal properties of the soil and change the features of the soil surface. Irrigation, for example, is the most essential factor in increasing crop growth and yield. However, due to rising human needs, water supply is unequal and insufficient (Wu and Cosgrove, 2000). There has been a renewed interest in enhancing water productivity as concerns about the use of restricted water resources have grown (Tennakoon and Milroy, 2003). Irrigation water management could be improved by increasing irrigation efficiency (Hou *et al.*, 2007). Drip irrigation is growing more popular around the world as a result of the controlled irrigation rate that meets the needs of a crop at all stages of growth (Mmolawa and Or, 2000). Adoption of drip irrigation technology in combination with mulch has the potential to conserve soil water, boost crop yields, and reduce soil temperature (Luo *et al.*, 2013).

Mulching has been shown to affect soil temperature and moisture content, as well as crop output (Li *et al.*, 1999, Acharya *et al.*, 2005, Ramalan and Nwokeocha, 2000; Li *et al.*, 2001). One of the most critical soil factors impacting cotton growth and development is soil temperature. Mauney (1986) suggested that all processes squaring, blossoming and boll initiation, maturation and boll opening are temperature sensitive. Crop development is slowed and fruiting abortion occurs as a result of high temperatures. Cotton grows best at temperatures between 20 and 30°C (Reddy *et al.* 1991), but it may also be grown at temps above 40 °C. Crop growth is harmed by prolonged severe temperatures. Mulching has the potential to improve crop growth, productivity, and soil water conservation by lowering soil temperature. Straw mulching reduce soil disturbance and increase residue accumulation at the soil surface, they can conserve soil water and reduce temperature (Baumhardt and Jones, 2002; Zhang *et al.*, 2009). In agriculture, soil mulching with plastic film has been widely used to reduce water loss and regulate soil temperature more evenly (Zhang *et al.*, 2005). However, the harmful effects of high temperatures can be mitigated by mulching with appropriate materials (Kader *et al.*, 2017). According to Zong *et al.* (2020), soil moisture was considerably lower (31.74%) in the no mulch condition than in the polythene mulch treatment. Meanwhile, soil temperature was greater (4.12%) in the polythene mulch treatment than no mulch.

There Although several studies have examined the beneficial effects of irrigation and mulching management in rain-fed farming systems (Wang *et al.*, 2001; Zhang *et al.*, 2005; Zhang *et al.*, 2009), the majority of these studies have focused on a single field water management practice; few studies have focused on farmlands with a variety of field management practices. We wanted to see how irrigation and mulching affected soil moisture (at depths of 0–15 cm and 15–30 cm) and soil temperature (at depths of 0–10 cm) in the upper soil layer.

MATERIALS AND METHODS

The field experiments were conducted at Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India (28^{o} 01′N latitude and 73^{o}22′E longitude at an altitude of 235 meters above mean sea level) during *kharif* season of 2019 and 2020. The soil of experimental field was loamy-sand, alkaline in reaction (pH 8.4 & 8.5) having 103.5 & 101.3 kg ha^{-1} available N (Alkaline permanganate method, Subbiah and Asija, 1956), low level of available phosphorus of 15.1 & 15.4 kg ha^{-1} (Olsen's method , Olsen *et al*., 1954) and medium in available potassium of 173.7 & 172.5 kg ha^{-1} (Flame photometric method, Metson, 1956) in 0-15 cm soil depth at the start of the both experiments. The experiment comprising total 20 treatment combinations; five level of irrigation (0.30 PE, 0.45 PE, 0.60 PE, 0.75 PE through drip irrigation on alternative day and 0.75 IW/CPE ratio through surface irrigation) and four mulches (no mulch, dust mulch, straw mulch and polythene mulch) in split plot design with three replications. Cotton variety 'RCH-650 BG-II' was sown on 23.05.2019 and 24.05.2020 with using 1.8 kg seed ha^{-1} at the spacing of 100 × 60 cm. All the recommended package of practices was followed to raise the crop.

A. Soil moisture content

Moisture content of 0-15 and 15-30 cm profile layers was determined at 60 and 120 DAS by thermo gravimetric method. Moisture storage in different soil layers was computed as follows:

Moisture (per cent) =

$$\frac{\text{Fresh weight (g)} - \text{Dry weight (g)}}{\text{Dry weight (g)}} \times 100$$

B. Soil temperature

Soil temperature was measured with the help of mercury in glass thermometer (soil thermometer) placed at 10 cm depth from all the replications at 14.30 hours at 60 and 120 DAS.

C. Water use (field)

Data regarding water use in field presented in table 1 showed that in 2019, 2020 as well as on pooled mean basis, highest water use of 1232.0, 1096.5 and 1164.3 mm was recorded with 0.75 PE and lowest water use of 658.9, 571.9 and 615.4 mm was recorded with irrigation level of 0.30 PE, respectively.

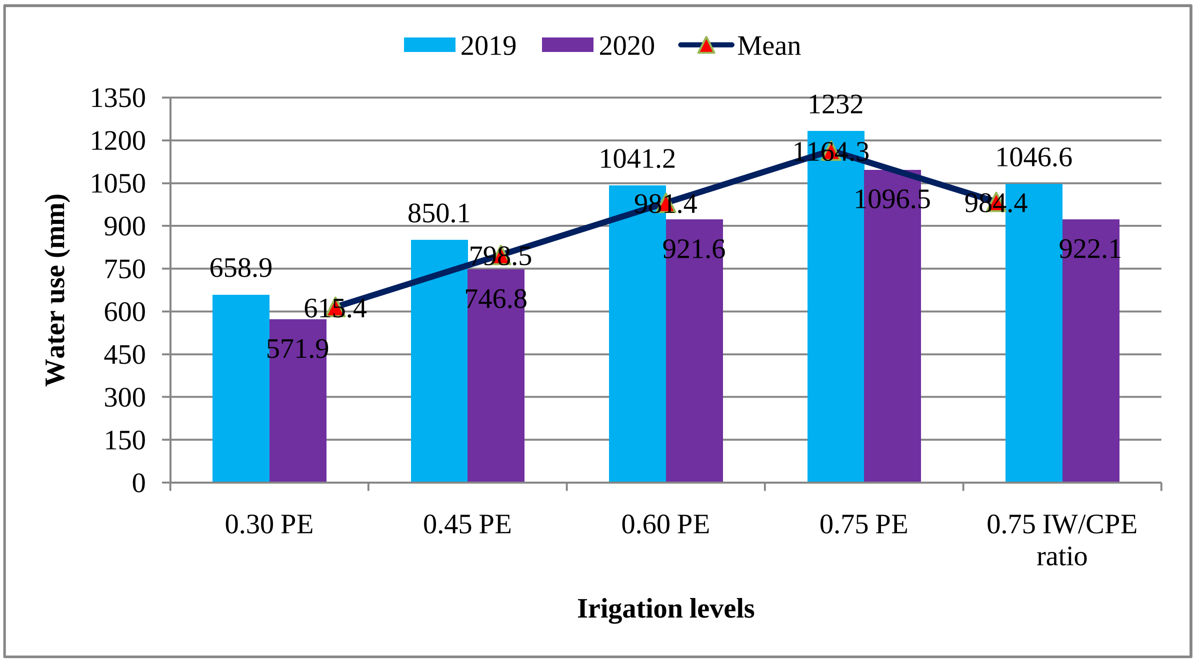

Fig. 1. Water use under dirrerent irrigation levels.

RESULTS AND DISCUSSION

A. Soil moisture content

Soil moisture content increased with increasing level of irrigation and soil depth (Table 1). Plot irrigated with 0.75 PE retained higher soil moisture at 0-15 and 15-30 cm soil depth at 60 and 120 DAS over 0.30, 0.45 and 0.60 PE during both the years. At 60 DAS plot irrigated at 0.75 PE retained higher soil moisture of 10.57 per cent at 0-15 cm and 10.71 per cent at 15-30 cm soil depth, which was higher over 0.30, 0.45 and 0.60 PE on mean basis. At 120 DAS plot irrigated at 0.75 PE retained higher soil moisture of 10.94 per cent at 0-15 cm and 11.20 per cent at 15-30 cm soil depth, which was higher over 0.30, 0.45 and 0.60 PE on mean basis. Increase in soil moisture at higher irrigation level due to optimum soil moisture maintained by regular irrigation. In contrast, at lower levels of irrigation low quantity of water applied that evaporated into atmosphere and absorbed by plant rapidly which led to low soil moisture. Hallikeri (2008) reported that irrigation at 0.8 (19.4 and 21.7 per cent) and 0.6 (19.3 and 21 per cent) IW/CPE ratio recorded higher soil moisture content at 30 cm soil depth at 90 DAS and at harvest, respectively over 0.4 IW/CPE ratio (17.1 per cent). Results corroborated with the findings of Das (2014) and Wheeler *et al.* (2020). Among mulch treatments, mulched plots retained higher soil moisture than no mulch at 60 and 120 DAS during both the years. Among mulching, polythene mulched plot retained maximum soil moisture at 0-15 and 15 -30 cm soil depth as compared to dust mulch and straw mulch. At 60 DAS polythene mulched plot retained 10.83 per cent and 10.94 per cent higher soil moisture at 0-15 cm and 15-30 cm soil depth, which was higher over no mulch, dust mulch and straw mulch, respectively. At 120 DAS polythene mulched plot retained higher soil moisture of 10.49 per cent at 0-15 cm and 11.63 per cent at 15-30 cm soil depth, which was higher over no mulch, dust mulch and straw mulch. The beneficial effects of mulching in the surface soil can be explained through reducing water loss through evaporation as crop residues at the soil surface shaded the soil (Huang *et al.*, 2005) and served as a vapor barrier against moisture losses from the soil (Mulumba and Lal, 2008). Sauer *et al.* (1996) found that the presence of crop residues on the surface reduced soil water evaporation by 34-50%. Mukherjee *et al.*, (2010) observed that actual evapotranspiration rate was 1.82 mm day^{-1} that declined by 31% with residues mulch.

B. Soil temperature

Effect of irrigation levels. Data presented in Table 2 indicated that soil temperature significantly influenced due to irrigation levels and mulches during both the years. Soil temperature from 10 cm soil depth in each treatment was recorded at 14:30 hours at 60 and 120 DAS. Increasing level of drip irrigation favorably decreased the soil temperature throughout the growing season. It was observed that maximum soil temperature was observed under 0.30 PE followed by 0.75 IW/CPE ratio, 0.45 and 0.60 PE. Minimum soil temperature was observed at 0.75 PE during both the years. The cooling effect of drip irrigation is related to the average daily soil temperature, with large extent of temperature reduction occurred on days when the soil was warmer. Results corroborated with the previous findings of Das (2014) and Wheeler *et al.* (2020).

Table 1: Effect of irrigation levels and mulches on soil moisture content under drip system.

Treatments	Soil moisture content (per cent)											
	60 DAS						120 DAS					
	0 – 15 cm depth			15 – 30 cm soil depth			0 – 15 cm depth			15 – 30 cm depth		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Irrigation levels												
0.30 PE	5.84	5.73	5.79	6.30	6.34	6.32	7.86	7.68	7.77	6.27	6.20	6.24
0.45 PE	7.72	7.90	7.81	8.94	8.96	8.95	8.17	8.27	8.22	7.14	7.01	7.08
0.60 PE	9.42	9.02	9.22	10.34	10.23	10.29	9.26	9.44	9.35	10.11	10.52	10.31
0.75 PE	10.46	10.68	10.57	10.66	10.77	10.71	10.95	10.92	10.94	11.17	11.22	11.20
Mulches												
No mulch	6.74	6.94	6.84	7.86	7.68	7.77	7.48	7.61	7.54	8.66	8.10	8.38
Dust mulch	7.01	7.14	7.07	8.17	8.27	8.22	7.55	7.74	7.65	8.79	8.15	8.47
Straw mulch	8.71	8.56	8.64	9.26	9.44	9.35	8.85	8.76	8.80	10.87	10.83	10.85
Polythene mulch	10.98	10.69	10.83	10.95	10.92	10.94	10.63	10.36	10.49	11.37	11.88	11.63

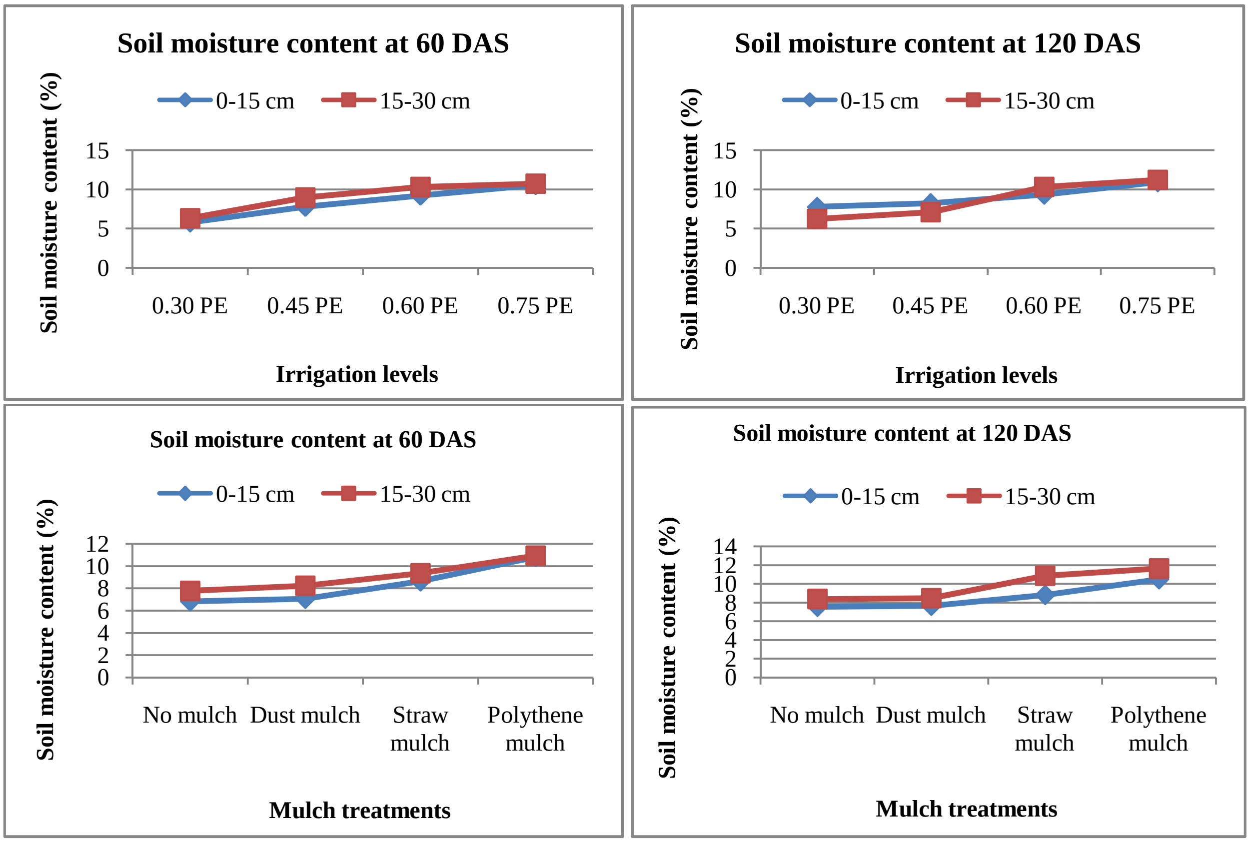

Fig. 2. Effect of irrigation levels and mulches on soil moisture content under drip system.

Soil temperature influenced due to mulch treatments during both the years. Soil temperature from 10 cm soil depth in each treatment was recorded at 14:30 hours at 60 and 120 DAS. Application of mulch favorably affected the soil temperature throughout the growing season. It was observed that maximum soil temperature was observed under polythene mulch followed by dust mulch and no mulch. Soil temperature lowered down by the straw mulch application. Straw mulch (36.4, 36.6 and 36.5°C at 60 DAS and 35.2, 35.4 and 35.3 °C at 120 DAS) lowered the soil temperature by 4.6, 5.4 and 5.0 °C at 60 DAS and 5.7, 6.1 and 5.9°C at 120 DAS as compared to no mulch, dust mulch and polythene mulch, respectively. Maximum soil temperature was 43.4, 44.7 and 44.1°C at 60 DAS and 43.5, 44.6 and 44.0°C at 120 DAS under polythene mulch plots whereas, 41.0, 42.0, 41.5°C at 60 and 40.9, 41.5 and 41.2°C at 120 DAS in no mulch plots during both the years and mean basis. Increase in soil temperature under polythene mulch and minimum soil temperature under straw mulch had been also reported by Tariq *et al.* (2016). These findings confirmed with Diaz-Perez *et al.* (2002), Sinkevigiene *et al.* (2009) and Das *et al.* (2015). Further, Kumar and Dey (2012) found that hay mulch is more effective than black polythene mulch in lowering maximum soil temperature. Kader *et al.*

(2019) analyzed that mulches conserved the soil moisture and maintained soil temperature. Sekhon *et al.* (2008) reported that straw mulch lowered maximum temperature up to 8.9°C. Daiya *et al.* (2007) also observed that application of straw mulch reduced soil temperature.

Table 2: Effect of irrigation levels and mulches on soil temperature.

Treatments	Soil temperature (°C) at 10 cm soil depth					
	60 DAS			120 DAS		
	2019	2020	Mean	2019	2020	Mean
Irrigation levels						
0.30 PE	42.6	43.7	43.2	42.8	43.5	43.2
0.45 PE	40.9	41.8	41.3	40.2	41.2	40.7
0.60 PE	38.4	39.0	38.7	37.8	38.2	38.0
0.75 PE	37.3	37.9	37.6	36.3	36.7	36.5
0.75 IW/CPE ratio	40.8	41.7	41.3	40.5	41.3	40.9
Mulches						
No mulch	41.0	42.0	41.5	40.9	41.5	41.2
Dust mulch	39.2	39.9	39.6	38.6	39.2	38.9
Straw mulch	36.4	36.6	36.5	35.2	35.4	35.3
Polythene mulch	43.4	44.7	44.1	43.5	44.6	44.0

CONCLUSION

On the basis of present experiments, it may be concluded that cotton crop irrigated at 0.60 PE through drip irrigation and mulched with straw retained higher soil moisture and lowered soil temperature.

Acknowledgments. The authors gratefully acknowledge the Department of Agronomy, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner for facility support during the research.
Conflict of Interest. None.

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How to cite this article: Shri Rakesh, S.R. Bhunia, S.M. Kumawat, N.K. Pareek, R.S. Rathore and Amaratpal Singh (2021). Hydrothermal conditions of Cotton Field under different Irrigation Levels and Mulches. *Biological Forum – An International Journal*, *13*(4): 1286-1291.