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Evaluating the Effect of Plastic Mulching and Irrigation Amount on Soil Moisture Distribution

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Authors' contributions

This work was carried out in collaboration among all authors. Author AS designed the study and wrote the first draft of the manuscript on evaluating the effect of plastic mulching and irrigation amount on soil moisture distribution. Authors ST and ES helped in collecting experimental data and managed the analysis of study. All authors read and approved the final manuscript.

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ABSTRACT

In India, the irrigated area comprises about 36% of the net sown area. Currently, the agricultural sector accounts for about 83% of all water uses. Drip irrigation system uniformity can maintain a higher crop yield and reduce the initial investment of cost. The study was conducted at precision farming development centre research farm, Tamil Nadu Agricultural University, Coimbatore, to evaluating the effect of plastic mulching and irrigation amount on soil moisture distribution. Two types of black plastic mulch of different thickness and one control without mulch were selected for the study M_1: 25 micron thickness Black Plastic mulch, M_2: 50 micron thickness Black Plastic mulch, and M_3: No mulch (Control). Three levels of fertigation were adopted, namely 80%, 100% and 120% of Recommended Dose of Nitrogen (N), Phosphorous (P) and Potassium (K) and are denoted as F_1, F_2 and F_3. The Coefficient of Variation (CV) was attained as 0.0308% kept at a constant pressure of 52 kPa, Statistical Uniformity (SU) as 97% and Uniformity coefficient as 0.97. As the elapsed time increased, the rate of increase of wetted diameter decreased. A high Coefficient of Determination

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(R^2) value of 0.97 indicates the goodness of fit for the horizontal movement. The average soil moisture distribution 40% was noticed below the emitter at the depth of 10 cm immediately after irrigation.

Keywords: Black plastic mulch; soil moisture distribution; uniformity coefficient; wetted diameter.

1. INTRODUCTION

In 2025, 33% of India's population will live under completely water scantiness condition [1]. Among all the irrigation methods, the drip irrigation is the most effective and it tends to be practised in a large variety of crops, mostly in vegetables, orchard crops, flowers and plantation crops. Drip irrigation involves furnish water to the soil very close to the plants at very low flow rates (0.5 to 10 litre per hour) from a plastic conduit fitted with outlets (drip emitters). The soil moisture remains at an optimum level with frequent irrigations. Water application efficiency was found in drip irrigation about 90 to 95%. In India, there has been an enormous growth in the area under drip irrigation during the last 15 years. This might be as low as 30% of the volume of soil wetted by other methods. Drip Irrigation obtain high uniformity, usually over 90 per cent, and wets only the part of root zone. The wetting pattern differs with the emitter and soil type. Wetting patterns during application generally comprises of two zones: (i) a saturated zone near to the drippers and (ii) a zone where the water content declines toward the wetting front [2]. Increasing the discharge rate generally found in a decrease in wetted depth and increase in wetted soil diameter. Moisture distribution pattern is one of the basic requirements for efficient design and management of an irrigation system. The knowledge of moisture distribution pattern helps in the effectiveness of drip irrigation [3]. The extent of soil wetted volume in an irrigation system determines the sufficient amount of water needed to wet the root zone. Soil water stored in the root zone was determined by the volume of wetted soil. Hence the present study had been conducted to fulfill the following objectives are (i) To evaluate the coefficient of uniformity under drip irrigation system in chilli. (ii) To examine the soil moisture distribution pattern in drip irrigation system.

2. MATERIALS AND METHODS

The experiment was laid out during 2013 to 2014 under irrigated condition, to evaluate the effect of plastic mulching and irrigation amount on soil moisture distribution. Sandy clay loam is the soil type of an experimental area. The soil is sodic in reaction with a pH of 8.07 and electrical conductivity of 0.78 dS/m. The experiment was laid out in Factorial Randomized Block Design (FRBD) with the treatments mulching thickness and fertilizer levels. All treatment combination is replicated thrice. Two types of black plastic mulch of different thickness and one control without mulch were selected for the study M_1: 25 micron thickness Black Plastic mulch, M_2: 50 micron thickness Black Plastic mulch, and M_3: No mulch (Control) (Table 2). Three levels of fertigation were adopted, namely 80%, 100% and 120% of Recommended Dose of N, P and K and are denoted as F_1, F_2 and F_3.

2.1 Irrigation Scheduling

Irrigations were planned based on climatological approach on mulch and control plots. Life-saving irrigation was given immediately after transplanting and the field was routinely irrigated continuously for ten days. After the tenth day, subsequent irrigations were planned once in three days on the basis of following formula and applied each time as per the treatment schedule.

$$WR = CPE \times K_p \times K_c \times W_p \times A \quad (1)$$

Where,

WR - Computed water requirement (litre/plant)
CPE - Cumulative pan evaporation for three days (mm)
K_p - Pan factor (0.8)
K_c - Crop factor
W_p - Wetted fraction (0.8)
A - Area per plant, m^2

$$\text{Time of operation} = \frac{\text{Volume of water required x Irrigation interval}}{\text{Dripper discharge}} \quad (2)$$

2.2 Discharge Uniformity Assessment

The discharge rate of the emitters at selected points in some laterals were measured by collecting the water for a known time directly under the emitters with the help of a measuring jar and stopwatch at 52 kPa operating pressure which was maintained throughout the experiment.

Table 1. Treatment details

Treatments	Mulching sheet
$T_1 M_1$	80% RDF with 25 micron thickness with Black plastic mulch
$T_2 M_1$	100% RDF with 25 micron thickness with Black plastic mulch
$T_3 M_1$	120% RDF with 25 micron thickness with Black plastic mulch
$T_3 M_2$	80% RDF with 50 micron thickness with Black plastic mulch
$T_5 M_2$	100% RDF with 50 micron thickness with Black plastic mulch
$T_6 M_2$	120% RDF with 50 micron thickness with Black plastic mulch
$T_7 M_3$	80% RDF with No mulch
$T_8 M_3$	100% RDF with No mulch
$T_9 M_3$	120% RDF with No mulch

2.3 Coefficient of Variation (Cv)

Coefficient of variation was determined for the drip irrigation system from flow rate measurements of several identical emission devices and was calculated with the following equation by [4]

$$Cv = \frac{\left[q_1^{\,2} + q_2^{\,2} + q_3^{\,2} + \ldots + q_n^{\,2} - n\bar{q}^{\,2}\right]^{1/2}}{\bar{q}\left[n-1\right]^{1/2}} \quad (3)$$

Where,

q_1, q_2, q_3 & q_n - Discharges from different segments
q Average discharge for the total segments
n No. of segments

2.4 Statistical Uniformity

The statistical uniformity was calculated with the following equation by (ASAE, 1993b)

SU = 100 (1 – Cv) (4)

Where,

SU - Statistical Uniformity
Cv - Coefficient of variation

2.5 Coefficient of Uniformity

The discharge rate of emitter was recorded at randomly selected emitter points on 1St, 5th, 10th and 15th and last one on each lateral to work out the uniformity of drip system as per the procedure given by [4]. The coefficient of uniformity was calculated by the following formula:

$$E_u = 100\left[1 - \frac{1.27}{\sqrt{Ne}}Cv\right]\frac{Q_{\min}}{Q_{avg}} \quad (5)$$

Where,

Eu - Emission uniformity in %,
Ne - Number of point source segments
CV - The manufacture's coefficient rate in the system, lph
Q_{min} - The minimum discharge rate, lph
Q_{avg} - The average rate of discharge, lph

2.6 Soil moisture Distribution Pattern

The wetting pattern of soil under different mulches was obtained by taking moisture content at different horizontal distances and depths. To study the soil moisture distribution pattern in soil, samples were collected at surface and at a depth of 0, 10, 20 and 30 cm and distance at 0, 15, 30, and 45 cm from emitter along the horizontal direction. The samples were collected before, immediately, one day and two day after irrigation. The gravimetric method was used to find the soil moisture distribution pattern.

2.7 Wetted Zone Diameter

Field observations were observed to measure the horizontal movement of the wetting front over the surface of the field. The diameter of the wetting front was estimated over different periods of time during emission and the wetting front advance equation was developed.

3. RESULTS AND DISCUSSION

The following experimental findings are:

3.1 Irrigation Scheduling

The amount of water applied per plant for chilli in Table 2.

3.2 Discharge Uniformity Assessment

The effectiveness of drip irrigation depends upon the uniformity of distribution of water throughout the field area. The discharge from the emitter at different points of emission was measured at a particular period of time at 52 kPa. The Coefficient of Variation (CV) for drip irrigation system is calculated as 0.0308% with the pressure of 52 kPa. Statistical Uniformity of the system was calculated as 97%. The Coefficient of Uniformity of the drip irrigation system was calculated as 96%. The high value of the coefficient of uniformity suggested that excellent performance of drip irrigation system in supplying water uniformly throughout the laterals.

3.3 Wetted Zone Diameter

The diameter of the horizontal wetted zone during different durations of emission is graphically presented in Fig. 1. As the elapsed time increased, the rate of increase of wetted diameter decreased. This was owing to the increased area for downward movement of water as the lateral wetting increased. A regression equation of type Y= AX+B was fitted to the horizontal advancement for 4 litre per hour emitter in sandy clay loam soil. A high R^2 value of 0.97 indicates the goodness of fit for the horizontal movement. The equation fitted was D = 0.153 t + 21.64. The behaviour of horizontal wetted diameter versus time confirmed the findings of [5,6] and [7].

Table. 2. Quantity applied per plant for coimbatore chilli Hybrid 1 - (COCH1)

Crop Date	Quantity applied per plant (lpd)	Duration of irrigation (min) each day	Total quantity (l) applied per plant per stage
Initial Stage (1-20 days)	0.627	20.28	1.391
Vegetative stage (21 - 45 days)	0.313	12.90	0.759
Fruit setting stage (46 - 90 days)	0.682	28.54	7.103
Final stage (91 - 120 days)	1.258	49.75	11.28

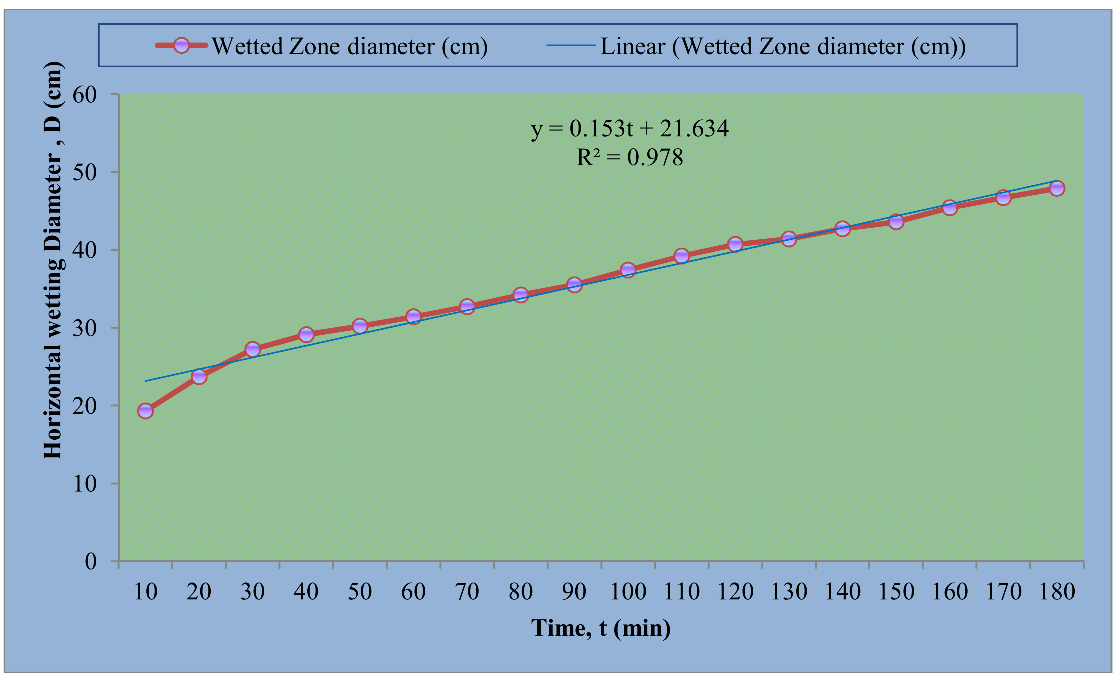

Fig. 1. The diameter of horizontal wetted zone

3.4 Soil Moisture Distribution Pattern

The soil moisture content at various depths, ie, surface, 0 to10, 10 to 20 and 20 to 30 cm at a different distance from the emitter were estimated just before, immediately, one day, and two days after irrigation. The average maximum soil moisture content 40 % was found below the emitter at the depth of 10 cm immediately after irrigation. The soil moisture contents found at different depths and distances from emitter were plotted by using the computer software package *"surfer"* of windows version and are shown in Figs. 2, 3, 4 & 5. The reason for increase moisture content in the lower horizons might be due to water stored in soil pores with minimum evaporation loss. Soil moisture content was low in the surface layer than in depths at different locations from emitter. This may because of more evaporation from the soil surface compared to lower layers. Similar results were reported by [8,9,10] and [11], that the moisture content was gradually decreased while the distance from the emitter increased. Soil water content was relatively higher by volume near the emitter and it was decreasing as the distance from the emitting point increased [12].

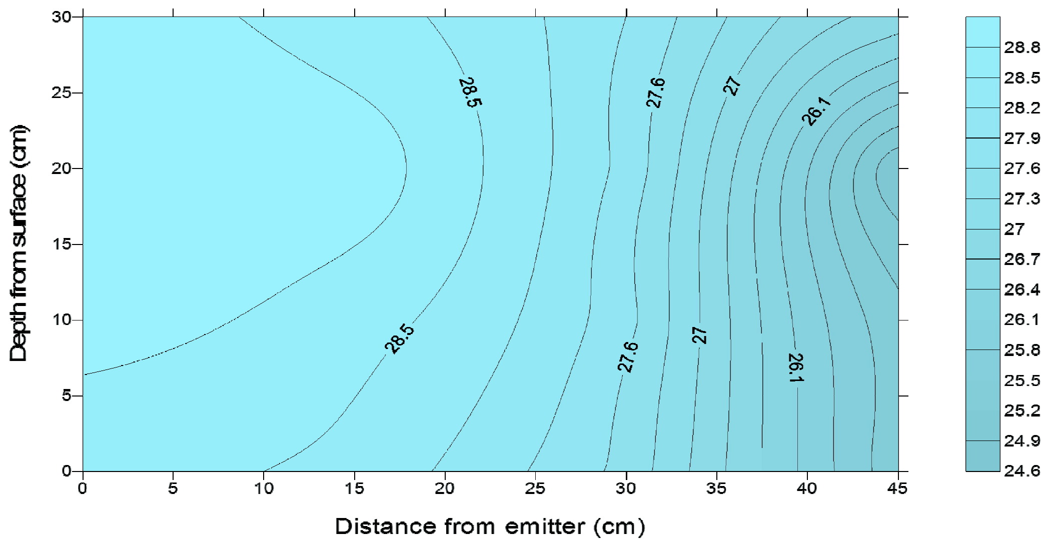

Fig. 2. Moisture content before irrigation

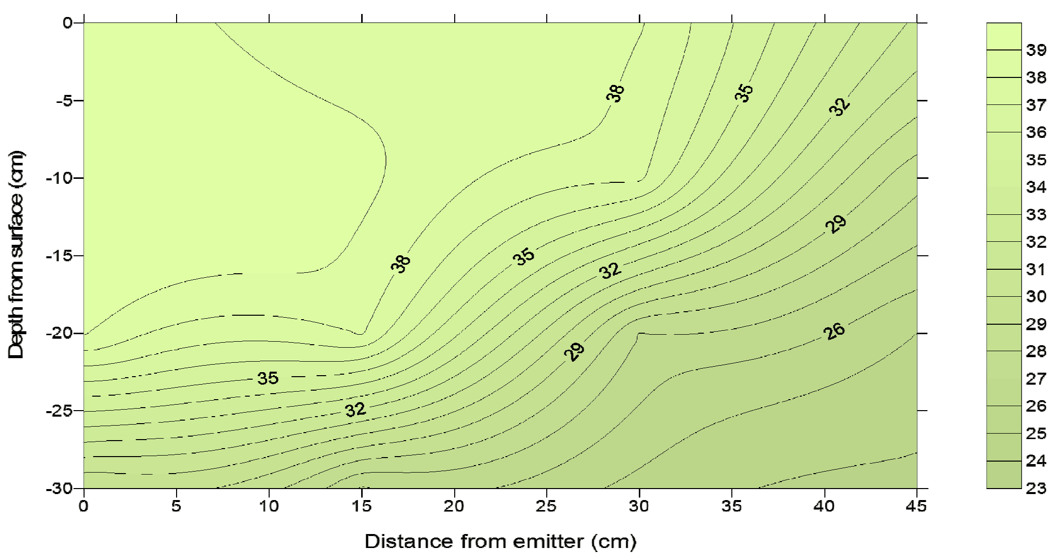

Fig. 3. Moisture content after irrigation

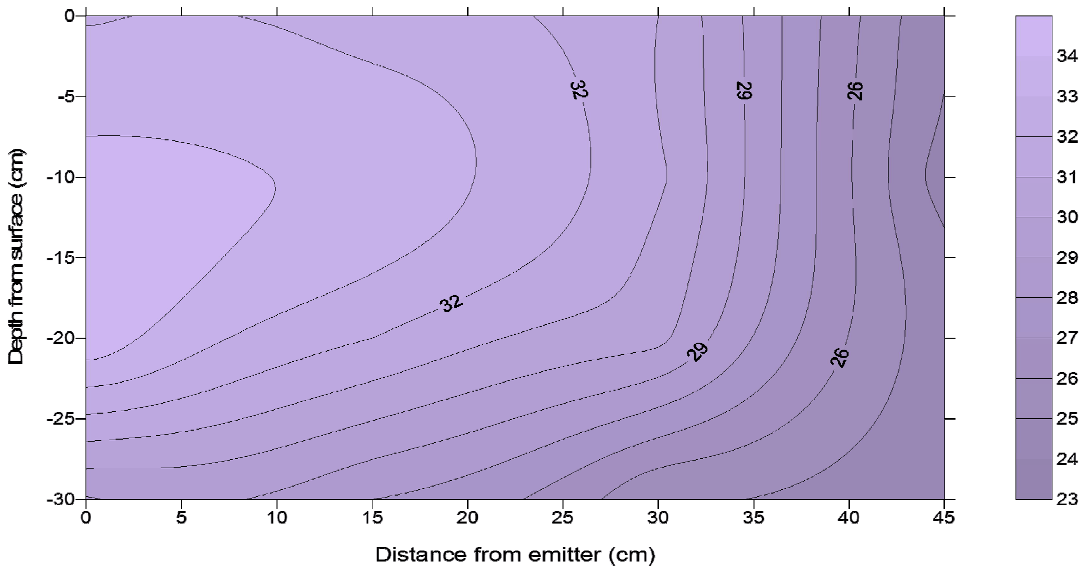

Fig. 4. Moisture content one day after irrigation

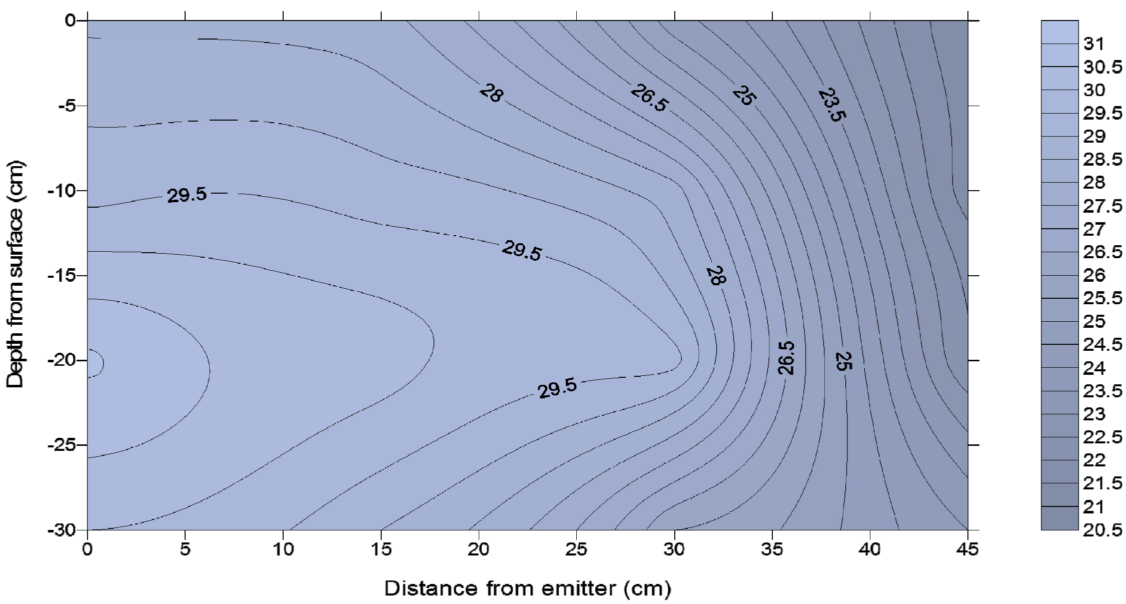

Fig. 5. Moisture content two days after irrigation

4. CONCLUSION

The Coefficient of variation (CV) was calculated as 0.0308% kept at a constant pressure of 52.00 kPa, Statistical Uniformity (SU) as 97% and Uniformity Coefficient as 0.97. As the elapsed time increased, the rate of increase of wetted diameter decreased. A high R^2 value of 0.97 indicates the goodness of fit for the horizontal movement. The equation fitted was D = 0.153 t + 21.64. The average maximum soil moisture content 40% was calculated below the emitter at the depth of 10 cm immediately after irrigation. The soil moisture contents found at different depths and distances from emitter were plotted by using the computer software package *“surfer”* of windows version.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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