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Effect of Drip Irrigation Combined Organic Mulching on Water Productivity and Yield of Tomato (*Lycopersicon esculentum* L.)

K. Ashok Kumar, M. Navaneetha, B. Aravind,
T.M. Rajesh, M. Pravallika, P.V.K. Jagannadha Rao

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ABSTRACT

Background: The main challenge confronting both rainfed and irrigated agriculture is to improve water use efficiency (WUE) and sustainable water use for agriculture. A field experiment was conducted during early summer season of 2020 to study the effect of drip irrigation combined with organic mulching on soil moisture, growth, yield of tomato grown on alfisols at the college farm of College of Agricultural Engineering, Madakasira, Ananthapuramu district of Andhra Pradesh.

Methods: The experiment was laid out in completely randomized block design (CRBD) with seven treatments comprising of various organic mulches. The treatments were T_1 - Sawdust + Irrigation based on daily crop water requirement, T_2 - Ragi straw + Irrigation based on daily crop water requirement, T_3 - Groundnut shells + Irrigation based on daily crop water requirement, T_4 - Groundnut shells + Irrigation once in every two days, T_5 - Saw dust + Irrigation once in every two days, T6 - Ragi straw + Irrigation once in every two days and T_7 - Control (without mulch) + Irrigation based on daily crop water requirement. All the treatments were replicated thrice. The plot size of each treatment was 4m × 2.5m.

Result: The results revealed that throughout the crop growth period, T_3 - Groundnut shells + Irrigation based on daily water requirement maintained soil higher moisture content to an extent of 132-146% as compared to control T_7 (Control + Daily water requirement). The fruit yield obtained with T_3 - Groundnut shells + Irrigation based on daily water requirement was significantly higher (8.8 t/ha) as compared to control T_7 (Control + Daily water requirement) (7.6 t/ha). The highest water use efficiency (39.6 kg/ha/mm) was noted with T_4 - Groundnut shells + Irrigation once in every two days), whereas T_7 (Control + Daily water requirement) registered minimum WUE (16.3 kg/ha/mm). Weed dry matter and weed index was found to be higher (50% to 100%) in T_7 (Control + Daily water requirement) throughout the crop growth period as compared to all the treatments applied with organic mulches. Our results indicated that T_{3} - (Groundnut shells + Irrigation based on daily crop water requirement) resulted in the highest plant height, number of fruits per plant and high water use efficiency as compared to without mulching. Further, under irrigation water constraints, groundnut shells mulch and drip irrigation once in two days was found to be effective in attaining higher WUE.

Key words: Drip irrigation, Organic mulches, Tomato yield.

INTRODUCTION

The changing climate under current situation led to depletion of available water resources, biotic and abiotic stresses such as raising temperatures, variability in rainfall, which drastically affected crop production. Hence, utilization of the available resources for sustainable agricultural production besides maintaining soil health is the need of the hour. In vegetable production, irrigation water plays key role in determining the productivity of vegetable crops. The concept of watering field noticed in conventional method has been changed to watering the individual plant through drip irrigation for increasing water use efficiency. For better results of drip irrigation, besides irrigating crop plants, loss of soil moisture through evaporation and transpiration processes through weeds have to be minimized. This can be achieved by covering the soil surface with material called 'mulch'. Mulch is primarily used in crop production for water and soil conservations; and weed growth (Patil *et al*., 2013). Surface mulching reduced soil evaporation and salinity hazards, (Yang *et al*., 2006); moderates the extreme soil temperature that is influenced by atmospheric temperatures, which favors optimum plant nutrient availability and ultimately crop growth. In recent years, usage of polythene mulches along with irrigation has been increasing in commercial vegetable production systems. However, excessive polythene usage poses certain problems like difficulty of removal, cost of disposal, increased soil erosion and increased agricultural chemical runoff (Brown and Channe Butcher 2001; Rice *et al*., 2001) and ultimately

College of Agricultural Engineering, Madakasira-515 301, Ananthapuramu, Andhra Pradesh, India.

Corresponding Author: K. Ashok Kumar, Department of Agronomy, ARS, Rekulakunta, Ananthapuramu-515 001, Andhra Pradesh, India. Email: koilakondaashok@gmail.com

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increasing soil pollution (Divya and Sarkar, 2019). Hence, an alternative to plastic (polythene) mulch is organic mulch, which is recyclable in the soil, reduce production cost and is environment friendly. Organic mulch keeps the surface layer wetter for an extended period and helps to increase root growth (Gajri *et al*., 1994), reduce day time temperature and conserve moisture, addition of organic matter (Oslen and Gounder, 2001), improves soil physical, chemical and biological properties, suppress the weed growth there by increased growth and yield attributes of vegetables (Rahman *et al*., 2006). Tomato is the important commercial vegetable crop grown in many parts of India that can be grown throughout the year. However, many farmers in Andhra Pradesh grow tomato during early summer to summer season under irrigated condition as they get higher market price and ultimately higher net returns. Majority of the tomato is grown with polythene mulching and under drip irrigated condition. Keeping in view the importance of organic mulching and drip irrigation the present field study was taken up to study the effect of various organic mulches combined with different drip irrigation schedule on soil moisture, crop and weed growth at various stages, fruit yield and water use efficiency.

MATERIALS AND METHODS

The field experiment was conducted during early summer season of 2020 at College farm, College of Agricultural engineering, Madakasira, Ananthapuramu, located at 13.56'58'' N latitude and 77.0 18'42" E longitude with an elevation of 641.6 metres above mean sea level. The mean annual temperature and annual rainfall of the study area are 25.7°C and 532 mm, respectively. Most of the rainfall (~ 80%) is received during south-west monsoon. The soils of the experimental site were alfisols with sandy clay loam in texture. The pH of soil was 8.35, EC of 0.37 mmhocm^{-1} and was low in organic carbon (0.35%), available nitrogen (205 kg ha^{-1}), phosphorus (54 kg ha^{-1}) and potash (136 kg ha^{-1}). The treatments were T1 - Sawdust + Irrigation based on daily crop water requirement, T2 - Ragi straw + Irrigation based on daily crop water requirement, T3 - Groundnut shells + Irrigation based on daily crop water requirement, T4 - Groundnut shells + Irrigation once in every two days, T5 - Saw dust + Irrigation once in every two days, T6 - Ragi straw + Irrigation once in every two days and T7 - Control (without mulch) + Irrigation based on daily crop water requirement. In all the treatments, except control, the soil surface was covered with different organic mulching material (saw dust, ragi straw and groundnut shells) up to a height of 5 cm as per the treatments. In control plot (T7), no mulching material was used. Further, the treatment plots T1, T2, T3 and T7 received irrigation based on daily water requirement, whereas T4, T5 and T6 treatment plots received irrigation once in every two days. All the treatments were replicated thrice. The plot size of each treatment was 4m × 2.5m. The treatments plots were irrigated through drip method of irrigation. The drip irrigation system was installed in the field after the experimental lay out. The drip irrigation system consisted of sub main line, lateral lines and gate valves. The sub-main line (30 m length) was laid out along the length of the experimental field. From the sub-main line, lateral lines of 15 m length were laid out across the plots i.e. along the crop rows and a spacing 45 cm was adopted between the lateral lines. The crop was irrigated through inline drip system which are spaced at 30 cm spacing. Irrigations were given to crop as per the treatments *i.e.* daily and once in every two days, gate valves were arranged at the junction of sub-main line with lateral lines to control the entry of water from sub main line into lateral line. Further, a water meter was installed to measure the amount of water given to crop. The tomato seedlings of 24 days old were used for transplanting at a spacing of 45 cm X 40 cm. The test hybrid was US 440, a prominent hybrid grown by farmers in the experimental region. A light irrigation was given to field before transplanting seedlings. The tomato crop was fertilized with 120 kg N, 80 kg P_2O_5 and 8 kg K_2O/ha. Also, gypsum @ 500 kgha^{-1} was added to soil for soil reclamation. Entire dose of phosphorus and potassium and 25% N dose was applied at the time of field preparation. Remaining dose of N was applied in 3 equal splits at 30, 45 and 60 days after transplanting. The nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate and muriate of potash, respectively. The tomato crop was irrigated through drip irrigation system with a lateral spacing of 45cm and emitter spacing of 30 cm. The irrigation was scheduled once in everyday up to 7 days and taken one day intervals as per the treatments. In the initial crop growth stage, leaf miner incidence was noticed, which was controlled by spraying monocrotophos @ 2 ml lit^{-1} of water. Tomato fruits were harvested manually at their maturity stage. The soil physical properties like bulk density, infiltration rate and field capacity of soil were determined before transplanting and after harvesting of crop. The soil samples were collected in each plot at 15 cm depth during the crop growth period and the soil moisture was estimated by gravimetric method.

The amount of water applied under each irrigation treatment was measured through water meters and expressed as total depth of water used in mm.

The actual crop evapotranspiration was (Eta) computed by multiplying the reference evapotranspiration (ETo) with crop coefficient (Kc) for different growth stages of the crop. ETo was calculated on a daily basis from daily meteorological data. The Kc for different growth stages taken according to FAO. Thus, volumetric water required for a tomato plant was computed as:

$$\text{Eta (mm/day)} = \text{Kc} \times \text{ETo}$$

Water use efficiency (WUE) was calculated using the formula below and was expressed in kg. kg$ha^{-1}\,mm^{-1}$

$$\text{WUE} = \frac{\text{yield (kg}ha^{-1}\text{)}}{\text{Amount of waterapplied (mm)}}$$

The weed index (WI) was calculated using the formula as below:

$$\text{Weed index} = \frac{X-Y}{X} \times 100$$

where,
X = Yield from minimum weed competition plot
Y = Yield from the treated plot

The weed control efficiency was calculated by the following formula

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

Where,
DMC = Dry matter of weed in control plot
DMT = Dry matter of weed in treatment plot
WCE = Weed control efficiency (%)

RESULTS AND DISCUSSION

Effect of drip irrigation schedules and organic mulches on crop growth and fruit yield of tomato

Plant height progressively increased with age of the tomato crop up to harvest in all the treatments evaluated. All the treatments applied with organic mulches registered significantly higher plant height as compared to control throughout the crop growth period (Table 1). Till 30 DAT, there was no significant difference in plant height among treatments receiving different organic mulches and irrigation schedules. However, during subsequent stages, significantly higher plant height was noticed in treatments applied with groundnut shells and irrigated either daily or once in every two days as compared to all treatments, except saw dust applied treatment that was irrigated on daily water requirement basis. The maximum plant height maximum was noticed in T3 - Groundnut shells + daily water requirement during the entire crop growth period and the increase in plant height was 32.7%, 26.8%, 47.7%, 51.4%, 39.6% and 49.3% higher as compared to control *i.e.* without mulching at 15, 30, 45, 60, 75 and 90 DAT.

The total number of fruits per plant was influenced due to mulching with organic material and without mulching. The treatment with groundnut shells application and irrigated either based on daily water requirement or alternate days registered significantly higher number of fruits per plant as compared to rest treatments (Table 2). Further, it was observed that across all the organic mulches, the number of fruits per plant did not vary significantly with respect to varied irrigation schedules that were evaluated in the study. Our results clearly indicated that tomato fruit yield varied considerably with organic mulches and drip irrigation schedules (Table 2). Significantly higher fruit yield was realized with ground nut shells as compared to all other organic mulching treatments. However, the variation with drip irrigation schedules with respect to all organic mulches did not vary significantly. The increased fruit yield with groundnut shells mulch was attributed to registering significantly higher number of fruits per plant. This increased

Table 1: Effect of various organic mulches on plant height content at different days after transplanting (DAT) during early summer season of 2020.

Treatments	Plant height (cm) DAT					
	15	30	45	60	75	90
T1 - Saw dust +Irrigation based on daily crop water requirement	19.1	32.1	42.3	54.6	63.3	69.3
T2 - Ragi straw + Irrigation based on daily crop water requirement	22.3	29.0	36.5	49.0	56.2	64.4
T3 - Groundnut shells + Irrigation based on daily crop water requirement	21.5	32.6	48.0	59.5	66.6	76.6
T4 - Groundnut shells + Irrigation once in every two days	20.3	28.4	45.3	54.2	62.0	70.5
T5 - Saw dust + Irrigation once in every two days	19.0	29.2	38.1	49.3	55.5	64.0
T6 - Ragi straw + Irrigation once in every two days	21.4	32.5	40.5	47.2	52.9	59.8
T7 - Control + Irrigation based on dailycrop water requirement	16.2	25.7	32.5	39.3	47.7	51.3
SEm (±)	1.2	2.0	2.2	3.0	3.0	3.3
CD (p=0.05)	3.6	6.0	6.4	8.8	9.0	10.5

Table 2: Effect of various organic mulches and drip irrigation schedules on number of fruits and fruit yield during early summer season of 2019-20.

Treatments	Number of fruits per plant	Fruit yield (tha^{-1})
T1 - Saw dust +Irrigation based on dailycrop water requirement	8	8.4
T2 - Ragi straw + Irrigation based on daily crop water requirement	8	8.6
T3 - Groundnut shells + Irrigation based on daily crop water requirement	10	9.8
T4 - Groundnut shells + Irrigation once in every two days	9	9.2
T5 - Saw dust + Irrigation once in every two days	7	8.2
T6 - Ragi straw + Irrigation once in every two days	7	8.1
T7 - Control + Irrigation based on dailycrop water requirement	6	7.6
SEm (±)	0.4	0.2
CD (p=0.05)	1.2	0.6

tomato yield may be due to better development of roots and vegetative growth, better nutrients uptake in mulched plots; improved soil microbial activity (Bhagat *et al*., 2016) and less normal leaching of nitrogen (Kundu *et al*., 2019) and improved soil physical properties (Orji and Eke, 2018). The next higher fruit yield was noticed in saw dust mulch and the lowest fruit yield was recorded in no mulch treatment. Similar findings were reported by Nagalakshmi *et al*. (2002).

Effect of organic mulches and different irrigation schedules on amount of water applied and water use efficiency in tomato crop

Water use efficiency

Among the two drip irrigation schedules evaluated, irrigation to tomato crop once in every two days resulted in half the amount of water applied as compared to drip irrigation schedule based on daily water requirement. Interestingly, application of water to tomato crop once in every two days with groundnut shells mulching resulted in higher water use efficiency (WUE) as compared to all other treatments (Table 3). The higher WUE with groundnut shells mulching and irrigated once in every two days was attributed to lower amount of water application and higher fruit yield, which was statistically similar with that of obtained with groundnut shells mulching and irrigated based on daily crop water requirement. This clearly indicated that the amount of water applied to the tomato crop can be reduced considerably by using organic mulches, which aids in reducing evaporation losses from the soil surface and enhanced utilization of available soil moisture by the root system that promoted crop growth, fruit yield and ultimately higher fruit yield and thereby higher WUE. Similar results in solanaceous vegetable crops were reported by Saikia, 2011.

Soil moisture content

For proper growth and development of the crop, sufficient soil moisture is a pre requisite so that the plants are not subjected to stress conditions. The efficient utilization of irrigation water can be attained by reducing the evaporation losses from soil surface to an extent of 25 -50%, as most of the applied water to crop is lost through evaporation (Hu *et al*. 1995). The evaporation losses from soil surface can be reduced by covering the soil surface with mulching material. Our results showed that covering the soil surface with organic mulches resulted higher soil moisture content as compared to control at different stages of crop growth. In our study, soil moisture content at 0-15 cm throughout the crop growth period was found to be higher in all the treatments receiving irrigation based on daily crop water requirement as compared to those treatments with irrigation once in every two days (Table 4). Among various organic mulches, higher soil moisture content was noted with groundnut shells under different drip irrigation schedules throughout the crop growth period, which might be attributed to better formation of an insulation like layer between the soil surface and outer environment This could have reduced the movement of water vapour from soil surface to outer atmosphere there by retention of more soil moisture.

Table 3: Effect of various organic mulches on amount of water applied and water use efficiency of tomato crop during early summer season of 2020.

Treatments	Amount of water applied (mm)	WUE (kg $ha^{-1}mm^{-1}$)
T1 - Saw dust +Irrigation based on daily crop water requirement	467	18.04
T2 - Ragi straw + Irrigation based on daily crop water requirement	467	18.4
T3 - Groundnut shells + Irrigation based on daily crop water requirement	467	21.0
T4 - Groundnut shells + Irrigation once in every two days	233	39.6
T5 - Saw dust + Irrigation once in every two days	233	35.3
T6 - Ragi straw + Irrigation once in every two days	233	34.8
T7 - Control + Irrigation based on dailycrop water requirement	467	16.3

Table 4: Effect of various organic mulches and different irrigation schedules on soil moisture content (%) at 0-15 cm depth at different days after transplanting (DAT) during early summer season of 2020.

Treatments	Soil moisture content (%) (0-15 cm depth) DAT				
	20	30	40	50	60
T1 - Saw dust +Irrigation based on daily crop water requirement	20.4	23.4	24.9	26.2	30.2
T2 - Ragi straw + Irrigation based on daily crop water requirement	24.4	27.2	26.8	29.2	33.4
T3 - Groundnut shells + Irrigation based on daily crop water requirement	20.7	24.2	31.2	34.2	38.2
T4 - Groundnut shells + Irrigation once in every two days	13.1	16.2	19.3	22.4	25.2
T5 - Saw dust + Irrigation once in every two days	12.4	15.1	17.4	19.8	21.2
T6 - Ragi straw + Irrigation once in every two days	11.2	14.6	16.9	18.2	20.5
T7 - Control + Irrigation based on dailycrop water requirement	8.9	10.3	11.3	13.9	15.5

Table 5: Effect of various organic mulches and different irrigation schedules on weed dry matter (gm^{-2}) at different days after transplanting (DAT) during early summer season of 2020.

Treatments	Weed dry matter (gm^{-2}) DAT		
	20	30	40
T1 - Saw dust +Irrigation based on dailycrop water requirement	6.1	38.0	62.1
T2 - Ragi straw + Irrigation based on daily crop water requirement	5.6	36.1	59.2
T3 - Groundnut shells + Irrigation basedon daily crop water requirement	4.7	27.0	44.4
T4 - Groundnut shells + Irrigation once in every two days	4.6	35.4	56.0
T5 - Saw dust + Irrigation once in every two days	5.1	32.1	54.0
T6 - Ragi straw + Irrigation once in every two days	5.2	34.0	59.2
T7 - Control + Irrigation based on dailycrop water requirement	19.1	59.0	81.1

Table 6: Effect of various organic mulches and different irrigation schedules on weed control efficiency (%) at different days after transplanting (DAT) and weed index (%) during early summer season of 2020.

Treatments	Weed control efficiency (%) DAT			Weed index (%)
	20	30	40	
T1 - Saw dust +Irrigation based on daily crop water requirement	68.1	35.6	23.4	14.1
T2 - Ragi straw + Irrigation based on daily crop water requirement	70.6	38.8	27.0	12.2
T3 - Groundnut shells + Irrigation based on daily crop water requirement	73.3	54.2	45.3	-
T4 - Groundnut shells + Irrigation once in every two days	76.0	40.5	30.9	5.91
T5 - Saw dust + Irrigation once in every two days	73.3	45.6	33.4	16.0
T6 - Ragi straw + Irrigation once in every two days	72.8	42.4	27.0	17.3
T7 - Control + Irrigation based on daily crop water requirement	-	-	-	22.3

Effect of irrigation levels and mulches on weed growth

Weed dry matter

In general, soil surface mulching results in lower weed growth as compared to without mulching. Our results clearly indicated that at 20, 40 and 60 DAT, significantly higher weed dry matter was noted with control as compared to all other treatments. Among various organic mulches, at all stages of crop growth, the treatment receiving saw dust mulching registered significantly higher weed dry matter per m^2. The lowest weed dry matter was noted in groundnut mulching treatment. Among different drip irrigation schedules, the higher weed dry matter was observed in daily water requirement compared to irrigation once in every two days (Table 5).

Weed control efficiency and weed index

The weed control efficiency estimated with different types of organic mulching material varied significantly. The groundnut shells mulch registered significantly higher weed control efficiency as compared to all other treatments. Among the drip irrigation schedules, at 20 DAT, higher weed control efficiency was noted in irrigation once in every two days However at 40 and 60 DAT, higher weed control efficiency was noted with irrigation based on daily crop water requirement under groundnut mulch treatment (Table 6). The control registered considerable lower WCE as compared to rest of treatments. Further, the control treatment resulted in higher weed index, whereas groundnut mulch with drip irrigation given once in every two days led to lower weed index (Table 6).

CONCLUSION

On the basis of experimental study, it can be concluded that T_{3} - (Groundnut shells + Irrigation based on daily crop water requirement) resulted in the highest plant height, number of fruits per plant and high water use efficiency as compared to without mulching. Further, under irrigation water constraints, groundnut mulch and drip irrigation once in two days was found to be effective due to higher WUE. It can be concluded that organic mulches were effective in maintaining higher soil moisture content, reduced weed growth and resulted better crop growth and there by improved yield parameters and achieved the highest fruit yield in tomato crop in alfisols of Andhra Pradesh.

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